Exploring the Nature of Cognitive Resilience Strategies

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Declaration

I, Jonathan David Day, confirm that the work presented in this thesis is my own. Where collaborations have been made with others, or where information has been derived from other sources, I confirm that this has been explicitly indicated in the text.

I grant powers of discretion to the City University Librarian to allow the thesis to be copied in whole or in part without further reference to the author.

Abstract

Where improving the safety or performance of a system, there is a tendency to focus on negative aspects surrounding human performance or interaction: errors, threats, past incidents or identified issues and flaws. This does not, however, tell the whole story. Users frequently deploy a variety of resilient interventions, devising and implementing strategies to improve performance and mitigate threats such as error- particularly during complex or challenging circumstances. In so doing, users can and do make an active, positive contribution to the wider resilience of a system. To date, the subject of how individual actors within a system leverage such resilience strategies to improve the functioning of said system is a topic that has received only limited direct investigation.

An initial study was undertaken as a probing investigation to test the notion of user-configured cues as a means to facilitate individual resilience. The insights from this study challenged an existing foundational categorisation scheme, which we then sought to expand and refine in collaboration with its original authors, to better represent and articulate 10 different types of resilience strategy. As a means to broaden our real-world pool of strategy accounts, a diary study was then conducted, the resulting data being used to both inform and validate a new iteration of the scheme. Stemming from challenges of the applicability of the scheme to complex resilience cases, we introduced the notion of a new type of *compound strategy*, and developed a framework to support their analysis by deconstructing them to examine their motivational and functional components. A final controlled laboratory study was undertaken to apply our insights. The resultant refined categorisation scheme and conceptual framework enrich our understanding of the phenomenon of user or individual resilience and could potentially be leveraged to inform and support the design of future technical and sociotechnical systems.

Preface

Jane's time is precious. She works in a busy hospital ward, and often has to juggle multiple tasks, in a stressful and unpredictable environment. This is why it is all the more frustrating when, after taking several minutes to compose an entry into the system, she clicks 'submit' and is greeted only by an error screen telling her the connection has been lost. Her Ethernet cable is loose, and this has caught her out before.

Fortunately, before clicking 'submit', Jane intentionally highlighted the text in the field and copied it onto the clipboard, so at least she won't have to type it all again.

She locates and reinserts the cable, however this time, she borrows an elastic band and uses it to hold the cable in place, better securing it, albeit temporarily.

Right at that moment, her watch begins to beep. This is the timer she set up earlier, telling her Mr Jenkins' infusion pump will shortly reach the end of its infusion.

She quickly opens up a window on the machine to compose a new email, and types 'tech support' into the subject heading, pasting the text she nearly lost in the body of the message. Also before leaving, Jane grabs a post-it note and scribbles '*Jane logged in, back in 5 minutes*', before sticking this note onto the centre of the screen.

Jane attends to Mr Jenkins, pre-emptively silencing the pump alarm, since his dementia causes him concern and agitation when these alarms sound.

After attending to him, she returns to her desk where the 'email' prompts her to paste the recovered text back into the system, and report the cable issue to tech support. She writes another note, to advise colleagues of the issue, and that it has been reported.

While the above account of Jane's conduct may be fictitious, the behaviours described within it are grounded in reality and readily observable. The propensity for people to adapt and problem-solve in the face of challenges and adverse conditions is a commonplace phenomenon, however the implications of this in some important settings and contexts are less well understood than one might expect.

The current thesis aims to provide insights into these resilience strategies and behaviours, and to better understand how we can learn lessons from them, particularly with regards to Human Computer Interaction.

Chapter 1: Introduction

1.1 Background and Motivation

One inevitable consequence of the advancement of technology is that the tasks people do, and the way they work, is fundamentally changing. The introduction of new devices and systems presents huge opportunities for improving efficiency and making tasks simpler and safer. However new issues and complexities are also raised, as interactive technologies introduce a new 'layer' of potential complication and error in the way people go about conducting tasks. While this premise applies across all manner of contexts and settings, nowhere is this point more pertinent than in safety critical work (e.g. the provision of healthcare), where the consequences of even relatively simple errors or mishaps all too often lead to serious injury or death.

It is against this backdrop that a large body of work investigating the *Human Computer Interaction* (hereafter abbreviated to *HCI*) of medical devices and systems has recently emerged. While the current thesis aims to remain somewhat domain-agnostic for reasons described later in 1.3, the work presented in this thesis forms part of a wider research project, *CHI+MED*, that specifically addresses HCI in a healthcare context, and explores how the application of HCI to medical technologies can enhance patient safety. Further information on the project is provided in 1.4.

Considering HCI in safety critical work can present significant challenges. Taking healthcare as an example, in addition to the safety critical nature and 'high stakes' of such work, the typical paradigm of interaction in frontline settings can often be highly dynamic, disruption-prone, and indeed chaotic. Multitasking is commonplace, juggling multiple and competing goals, and with an expansive set of potential stimuli competing for memory and attentional capacity, cognitive load can be extremely high. These inherent complexities make it difficult for HCI designers and practitioners to constrain and define the environments and scenarios in which their work will be realised. Implicit assumptions about the nature of a traditional interaction paradigm do not necessarily hold at the sharp-end.

The prevailing approach both in safety science and in HCI is to carefully consider this rich context, and in particular to learn from threats and challenges identifiable in situated interactions, both as observed/reported and as envisioned. This predominantly evolutionary and reactionary approach represents a clear and direct path to improving safety and reducing threats to performance such as error. Situations or challenges which occur frequently or are of high-impact, are catered-for almost by default, as flaws and hurdles are 'designed-out'. However, considering the innately unpredictable nature of the domain, a pragmatic perspective dictates that designers will never be able to fully account for *all* scenarios, and while it is a useful exercise to consider and envision perceived situated challenges, it is inevitable that some interactions will 'fall through the cracks'.

So what happens when situations extend beyond the envisioned design envelope, and interactions go 'off-piste'? In these cases, it falls to the user to manage threats and maintain their own performance, and that of the system which they are operating. This is a phenomenon that remains relatively unexplored in the literature.

The bulk of work within the literatures on safety science and human factors (including HCI) could be seen as possessing an inherent bias towards focusing on weaknesses and frailties in human performance, as opposed to positive, adaptive and resilient qualities (Hollnagel, Wears & Braithwaite, 2015). This represents a logical consequence of primarily directing focus towards accidents and adverse events, which naturally attract far more investigative scrutiny than normal practice or the unremarkable functioning of a system or interaction. The *Resilience Engineering* perspective (Hollnagel, Woods and Leveson, 2006) however posits that there is merit also in better understanding and nurturing these positive contributors to performance, in a complementary approach to the more established pursuit of minimising negative impactors on performance.

As noted by Furniss et al. (2011), much of the work conducted within the vein of Resilience Engineering has looked at building resilience into systems or procedures in a systemic high-level manner, promoting factors that enhance the resilience of organisations and sociotechnical systems. Furniss et al. proceed to

describe how the resulting insight is often at a somewhat high level of abstraction, leading to principles that apply well at system and organisational levels, but are more challenging for designers to envisage and implement at the sharp-end of situated interactions and operation for the individual user. Furniss, Back and Blandford (2012) for example discuss how Hollnagel's (2009) *Four Cornerstones* provide high-level support but can be difficult to trace back to concrete instantiations of resilience strategy use. This is a topic we return to discuss further in 3.3.2.

The current thesis aims to explore how this resilience engineering perspective can serve to inform and enhance HCI, specifically by considering how we can learn from the resilient, adaptive and positive interventions that individual actors or users take to mitigate or overcome challenges and maintain performance. We conceptualise these behavioural phenomena as *Resilience Strategies*, and seek insight into what strategies exist, how they are developed and deployed, and move towards considering the implications they may have in terms of the design of future interactive systems.

1.2 Research Questions and Contributions

In a broadest sense, the goal of the current PhD is to better understand resilience strategies and associated behaviours, with a particular interest in the role they play in users' interactions with technologies, to yield insights that could be applicable within safety-critical domains such as healthcare. As is discussed in more detail in 1.3 below however, we ultimately expand the scope of this work beyond the confines of interactions with technologies, and indeed also beyond the medical domain, in order to contribute more generalisable knowledge that is applicable to, but extends beyond, both HCI and the medical domain. The focus of this work is thus on the concept of resilience strategies in a more generic sense, combining a HCI-centric research approach with the Resilience Engineering perspective.

1.2.1 Research Questions

The current thesis posits three formal research questions, which are outlined below. Further to this, we discuss an additional, more 'forward-looking' broader aim reflecting the state of maturity of the of topic and how we ultimately suggest this work might progress towards concrete applications in terms of design.

RQ1: What constitutes a Resilience Strategy, and what different types of strategy exist?

The first research question we seek to address concerns the breadth or variety of strategies, in terms of the different classes or categories of strategy that exist. As described later in 2.2, the study of resilience strategies can be considered analogous to the study of error, in which a number of classifications and 'types' have been defined. The process of articulating different types of error has served as a valuable foundation to further the study of error, by scoping the space of potential errors and adding a structure and vocabulary to assist in their investigation. We propose that a more clearly defined working space, identifying differing types of resilience strategy, would yield similar merits and thus comprise a valuable first research question.

RQ2: How do different types of strategy 'work':- What are the underlying components that contribute to the make-up and effectiveness of a strategy?

Progressing from an improved understanding of the variety of types of strategy, we move towards investigating some of the intricacies of these different types of strategy, to better understand how and why they work. While our initial research question represents *breadth* in terms of identifying and disambiguating a selection of different types of strategy, this second research question concerns *depth*, in terms of investigating the structural elements and functional mechanisms that contribute to the effective working of a strategy.

RQ3: How can we develop effective processes to study Resilience Strategies, and what approaches can be harnessed to facilitate their investigation?

Owing to the relative infancy of investigations specifically targeting the study of resilience strategies, we do not yet possess a fully-formed understanding of appropriate ways to study the phenomenon. Therefore, a final research question arises that concerns the *approaches* that can be leveraged in order to improve our understanding of resilience strategies.

Finally, we additionally wish to consider as a broader aim the question of how insights gained in the process of addressing the aforementioned research questions can be applied in a practical sense in HCI design. This goal comprises a more long-term aim rather than a formal research question, as further work is very much required to comprehensively bridge the gap between the theoretical insights gained here and real-world practice at the 'sharp-end'. We do however present a brief, forward-looking discussion reflecting upon how the work described in this thesis could serve to facilitate future practical work, and translate into a foundation for future researchers and designers to reason about resilience.

1.2.2 Contributions

In addressing the above research questions, the work contained within this thesis seeks to provide a number of concrete contributions to the field, which are specified here together with the corresponding research questions they address.

As a precursor to approaching both RQ1 and RQ2, it is necessary to possess sufficient material for analysis, which in this case takes the form of a numerous and varied selection of resilience strategy examples. While a pool of strategy cases does already exist, as discussed later in 2.4, this current collection of strategy cases is limited both in terms of quantity and detail. Consequently, our first contribution, C1, is as follows:

C1. A broad set of real-world strategies, collected from a variety of complementary empirical approaches, expanding the existing limited pool of strategies, to provide material for analysis

Our next contribution, provided in Chapter 5, specifically seeks to address RQ1 by developing upon an existing but limited categorisation scheme for clarifying and articulating the variety of different types of resilience strategy:

C2. An expanded and refined categorisation scheme for classifying different types of strategy, that enriches the theory base to help us understand, reason about and communicate instances of resilience

Building upon an enhanced understanding of the variety of different types of strategy that exist, our next contribution seeks to understand some of these types of strategy in more detail, exploring how and why they function, addressing RQ2:

C3. A conceptual framework that helps researchers articulate and reason about the properties of complex examples of resilience strategies, identifying underlying components and how they relate

Finally, as more of a minor contribution, C4 below concerns potential future lessons in terms of research approaches for the future investigation of resilience strategies, addressing RQ4:

C4. The identification and development of a set of techniques to elicit, record and analyse instances of resilience

Figure 1, located in section 1.5 below (*Outline of Thesis Structure*) revisits these contributions and their corresponding research questions, providing a visual representation of how each maps onto the structure of the thesis, and where they are addressed.

1.3 Scope and Approach

While the current thesis is framed by a need to better understand the resilient behaviours and strategies (the potential distinction between which, is later discussed in more detail in 3.5) of users in a healthcare-HCI context, it is worth noting here that the scope of the work described in this thesis extends beyond this specific domain. As will later emerge in our discussion of the present literature surrounding the topic, our understanding of the behavioural phenomenon of resilience strategies even in a general sense is currently far from developed. We thus felt that to confine our investigations to the medical domain would be to place potentially an artificial constraint on the subject of this work; that it would be more valuable to aim towards an enhanced understanding of resilience strategies *per se* as opposed to attempting to confine our study of this somewhat ambiguous phenomenon within the constraints of one specific collection of tasks and settings.

As noted by Furniss, Back and Blandford (2012), one feature of the literature surrounding the related but distinct subject of error is that an established foundation of knowledge exists to provide a vocabulary by which to discuss the topic, including a number of taxonomies for classifying and differentiating different types of error. This helps to make the concept more tangible, and assists with more in-depth investigation and analysis of errors. While a developed pool of contextually-relevant literature exists in the form of work into safety and error, the literature specifically addressing the subject of resilience strategies unfortunately lacks such an established foundation, with the possible exception of early and limited work in the area by Furniss et al. themselves. Resulting from this, and leveraging the relatively recent emergence of the 'Safety-II' perspective (later discussed in 3.2.2), we noted an opportunity to further understanding of the topic of resilience strategies by developing this foundational account, which given the state of the field, represented a more fruitful pursuit than scoping our approach toward a narrower and more niche analysis of only the strategies that emerge from interaction with medical devices and systems.

Moreover, to consider the topic in a domain-agnostic fashion presents opportunities, both in terms of learning lessons from across domains which may be applicable in a medical context, and potentially producing findings that are generalisable across further settings and different types of work. A feature of resilience strategies that emerges from our investigation is that users employ different strategies in relation to different threats/challenges or opportunities that arise during the course of their tasks. Developing a broader understanding that transcends the specifics of individual tasks potentially reveals insights from one task that may be transferable to another, both within healthcare (e.g. prototypes of some strategies that emerge during interaction with blood glucose monitors may also apply to the programming of infusion pumps) and beyond (e.g. the strategies pilots deploy in the cockpit of an aircraft might also transfer to the programming of medical devices and vice versa). Similarly, by expanding our area of interest to all types of resilient strategies regardless of specific populations, tasks and environments, any findings we produce would by default be more generalisable across a broad variety of tasks and settings than would be the case if we focused exclusively upon the medical domain.

Another way in which we expanded our area of interest which is important to clarify is that although we adopt a HCI-centric approach to our investigation of the problem (borrowing from HCI research methods and leveraging existing insight from within the field), for similar reasons to those outlined above about the medical domain, we do not confine our investigations to only consider strategies that revolve around the use of computer systems or technology. Some strategies which individuals utilise that are devoid of technology (e.g. appropriating physical, real-world items) are highly analogous with strategies that also apply within the realm of technology (e.g. appropriating digital, on-screen items). We thus felt to focus solely on the use of technology, i.e. considering only the HCI-related implications and applications of the phenomenon, would restrict us from potential insights to be gained in a broader sense, and which could prove transferable. By broadening our focus to consider both technological and non-technological phenomena, this work

thus moves beyond the realm of solely HCI, into the broader sphere of human factors.

With regards to the approach we have taken during the progression of this work, it is also worth at this point briefly covering the reasoning behind our adoption of a somewhat unconventional combination of studies in a 'controlled laboratory' format (Chapters 4 and 8) and self-report diary studies (Chapter 6).

The initial study presented in Chapter 4 represented a probing study during which we attempted to closely scope the investigation into a subset of resilience strategies, only to encounter the challenges and weaknesses that arise from 'rushing in' to study a complex behavioural phenomenon upon which there is not an adequate foundation of existing theoretical knowledge. In a response to this, as described above, we opted in our next study to capture as broad and diverse a spread of strategies as we could, and the implementation of a diary study enabled us to sample a general population across all manner of tasks and settings. Returning to the lab for the final study represented a better-informed attempt to study resilience strategies in a more controlled manner, providing insight into how one might operationalise the phenomenon. It should also be noted that the use of these particular methods reflected the HCI-centric approach we adopted, based on the topic of the overarching research project, and on the background and experiences of the thesis author.

1.4 About the CHI+MED Project

The *CHI+MED* (Computer-Human Interaction for Medical Devices) project was an interdisciplinary, cross-institute research project aimed at reducing error and improving safety through investigation into interactive medical devices and their situated use. The project aimed to investigate and influence how these devices are designed, implemented and operated in the real-world, in an effort to improve patient safety and experience.

The project ran for 6 years beginning 2009, and was a flagship project of the UK EPSRC, from which it was funded (grant no. EP/G059063/1). The work described in this thesis was in turn conducted as part of, and funded by, the CHI+MED project.

The CHI+MED project brought together researchers from a variety of disciplines including computer science, psychology, HCI and cognitive science, combining a variety of approaches ranging from modelling and simulation through to detailed ethnographic investigation of situated use, with the aim of building a rich picture of typical medical device interaction and combining this insight with a foundation of multidisciplinary expertise to improve device design and increase patient safety.

The project was based across a number of UK universities (*City University London, Queen Mary University of London, University College London,* and *Swansea University*) and two hospitals (the *Royal Free* and *Singleton* Hospitals) collaborating with a variety of stakeholders including device designers, frontline medical practitioners, training and procurement staff and patient safety and regulatory bodies, both nationally and internationally.

The range of publications penned by CHI+MED researches reflects the diversity of the CHI+MED team, with topics ranging from public engagement to fine-grain key entry, from detailed analysis of display technologies to ethnographic exploration of setting. The area of resilience in turn forms just one topic within the wider CHI+MED project, however its relevance and importance is clear given the safety critical nature of the medical domain.

More information can be round regarding the CHI+MED project at http://www.chi-med.ac.uk

1.4.1 A Note on Collaborative Activities

The work undertaken and described in this thesis is the sole work of the thesis author, with the exception of two particular units of work which were conducted in collaboration with colleagues on the CHI+MED project and which are explicitly indicated later in the thesis (see 5.2 and 7.1). As such, where collective pronouns are used to denote ‘our’ work, or work ‘we’ conducted, this in actual practical terms denotes work undertaken solely by the thesis author. In cases where reference is made in the first-person to work undertaken collectively and in collaboration with colleagues, we denote this by using the phrase ‘the group’ to indicate the contributions of colleagues as listed in 5.2 and 7.1.

1.5 Outline of Thesis Structure

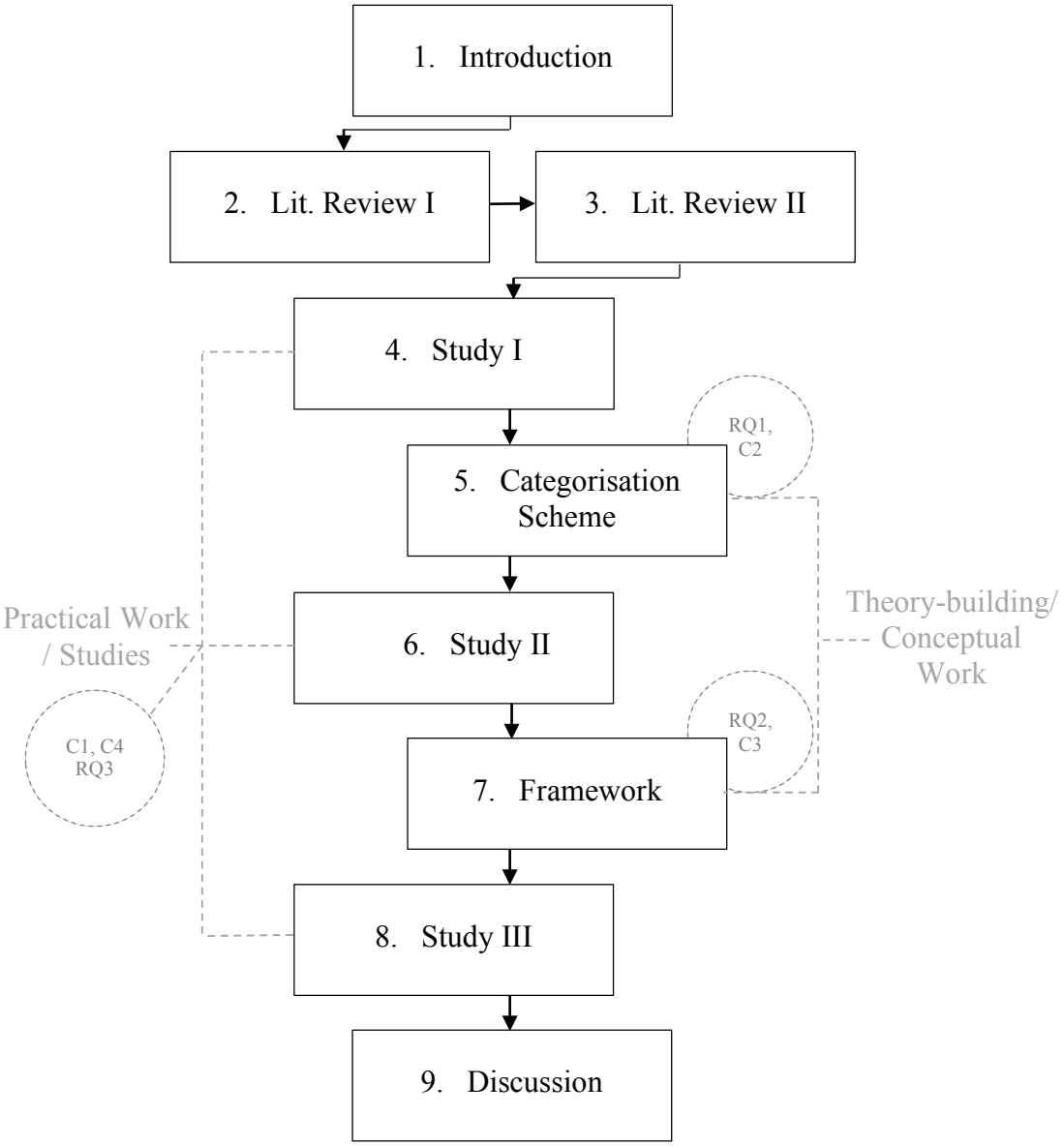


Figure 1: Outline of Thesis Structure

Chapter 1, the current introductory chapter, presents brief discussion of the broad background and motivations behind this work, the key intended contributions and research questions it addresses, the scope and approaches it adopts, details about the wider CHI+MED project, and the current document outline.

Chapter 2 represents the initial part of the literature review, which discusses current work and understanding specifically addressing the topic of resilience and the field of resilience engineering. The literature review of this thesis has been split into two chapters, reflecting the broad and multifaceted nature of the work upon which this thesis builds. The relatively recent *resilience engineering* perspective represents an important cornerstone of the conceptual approach adopted as a part of this thesis, and some of the work undertaken within this emerging discipline is of particular relevance and interest. However, as is also discussed, much of this resilience engineering work extends beyond the scope of the current project, while there are also important topics and concepts highly relevant for this thesis that appear absent from the resilience engineering literature.

Chapter 3 represents the second part of the literature review, and discusses a number of these topics and concepts which are highly pertinent to this work, however, which extend beyond the literature explicitly addressing resilience engineering by name. The core topic of this thesis lies at an intersection between a disparate and fragmented collection of topics which span the literatures across human factors and safety science, HCI, and psychology. Chapter 3 articulates and briefly addresses some of the key relevant concepts from this expansive body of work, as well as situating the specific topic within these interconnected fields.

Chapter 4 presents an account of the initial study conducted as part of this work, which was an exploratory, probing study conducted in a controlled laboratory format. The study was tasked with investigating the topic of cueing as a means to enhance performance, specifically how users may create and configure cues to assist with tracking place-keeping during interruptions. The chapter outlines the motivations and aims of this work, describes how the study was conducted, and presents a detailed discussion on the findings observed, lessons learned, and implications with regards to the subsequent direction of the PhD following the pivotal role of this study.

Chapter 5 presents discussion regarding the articulation of a set of concepts to denote different types of resilience-related strategies and behaviours, and in

particular discusses our contribution to refining and expanding a categorisation scheme to this end. This work follows on from the initial study as detailed in Chapter 4, and a key pre-existing study as outlined in Chapter 2.4, and discusses how the current work can both be informed by, and crucially also serve to inform, our current understanding of these different types of resilience strategy.

Chapter 6 presents a collection of diary studies that were conducted as a means to elicit an expanded pool of resilience strategies upon which to base analyses as previously described in Chapter 5, and validate further conceptual work later presented in Chapter 7. This comprises two rounds of a traditional, paper-based diary study (initially to capture information used in ideation and building a revised scheme, and later as a means to validate the resulting revised scheme).

Chapter 7 discusses lessons learned from scrutinising the earlier work presented as part of this thesis, and discusses what could be considered a conceptual shift in the way we frame the scheme presented in Chapter 5. The chapter introduces a conceptual framework to account for variation in the levels of abstraction by which strategies are discussed and analysed, proposing that some strategies may be considered compounds of sub-strategies, and exploring how we can unravel and deconstruct these complex cases to better understand how and why they work. The chapter closes with a discussion of the implications of this contribution.

Chapter 8 presents the final practical study conducted as part of this work, in which we return to a controlled laboratory study paradigm to elicit and record a broader array of types of strategy. This study applies some of the insights gained from throughout the course of our work, and in particular, develops on the practical approach of the initial study described in Chapter 4 and applies some of the lessons learned from that work. Again, discussion is presented on the motivations, methodology and conduct of the study, and in particular we analyse the subsequent findings and observations in the context of the improved analytical techniques arrived at through the conceptual work described in Chapters 5 and 7.

Chapter 9 closes the thesis with a summary discussion of the work undertaken during the course of this project, and our resulting key findings and

contributions. The chapter also goes on to present an evaluative discussion of this work, summarising lessons learnt, providing a critique of and describing the limitations of the work and suggesting further avenues for potential expanded investigation in the future. The chapter concludes with a discussion about how this work might serve to inform design, presenting a set of principles for practitioners in the HCI space to potentially leverage.

With regards to research questions and contributions as outlined previously in 1.2, RQ1 exploring the variety of strategies that exist is primarily addressed in Chapter 5, which also constitutes C2. RQ2 considering how strategies work is represented in Chapter 7, which also constitutes C3. RQ3 concerning research approaches, in tandem with C4, is represented in Chapters 4, 6 and 8, and also discussed in Chapter 9. C1, the collection of a pool of strategies, is also completed within the practical studies described in Chapters 4, 6 and 8.

Chapter 2: Literature Review I:

Resilience and Resilience Engineering

2.1 Chapter Introduction

As noted in the introduction, the literature review for this thesis has been divided into two chapters. This division reflects the identification of two pertinent, though distinct and separate, bodies of literature that have contributed to the work presented in this thesis. The first of these, discussed in the current chapter, is the topic of Resilience, and the emerging discipline of *Resilience Engineering*, which describes the targeted investigation and application of principles of resilience in a design and engineering context.

The following chapter will open with a brief word on the concept of resilience in the broader sense, as a grounding to introduce the research topic of Resilience Engineering. Work within and around the topic will then be discussed in terms of a number of complexities and 'dimensions' of resilience, identified from the literature. The presentation of these dimensions not only serves to frame the discussion of the topic within the current literature review, but has also served to shape the subsequent work later described within this thesis by articulating challenges and opportunities within the field.

The chapter closes with a more focused account of the work within Resilience Engineering that specifically targets the resilience of individuals or users, given the clear relevance this work has for the study of resilience from a Human Computer Interaction standpoint, as was specified from the outset of this PhD.

2.2 What is Resilience and What is Resilience Engineering?

Resilience, upon first glance, may appear a relatively graspable concept. It is, after all, something of an everyday term, frequently adopted across all manner of contexts and settings. In a broad sense the term implies adaptability, flexibility and

robustness, generally in the face of adverse conditions or events. Further connotations of endurance, toughness, and a sense of recovery, elasticity or 'bouncing back' are noted when one consults the multitude of dictionary definitions.

As a subject of study in academia, the term also sees widespread use across a diversity of topics, ranging from ecology to structural engineering; biomedical science to political science. The recurring sense of resistance, recovery and elasticity are however common threads that carry across contexts, and these qualities are of course also applicable to the conduct and behaviour of people. Adopting a Human Computer Interaction perspective, it is this last observation that forms an overarching motivation for the work discussed in this thesis.

When consulting the resilience-related literature targeting how *people* operate, the use of the term resilience could be said to primarily describe two distinct ideas and bodies of literature:

(i) At an individual level, the predominantly psychological way in which people cope with, or respond to, stressors, trauma or adversity (i.e. recovering from traumatic life events)

(ii) The relatively recent introduction of Resilience Engineering, within which the term largely describes the resilience of sociotechnical systems or actors (including human actors) within such systems

It is immediately noted that, while there is an individual or cognitive aspect of Resilience Engineering which the current work addresses, there is minimal overlap between this work and the former of these topics, the investigation of 'psychological resilience' (for want of a better term). The current work thus exclusively addresses the second of these topics, i.e. resilience in a Resilience Engineering context, and when we refer to the resilience of people or of individuals, it is with this framing in mind.

The Resilience Engineering (hereon abbreviated to RE) literature can largely be associated with a number of safety critical domains such as aviation, disaster relief, and more recently healthcare. Examples of resilience reported in the literature vary from the emergency services response to the terrorist attacks of September 11th 2001, the successful landing of a crippled passenger jet on the Hudson river, down to the use of sticky notes to draw attention to particular indicators in a nuclear plant control room (Tierney and Bruneau, 2007; Paries, 2011; Furniss, Back, Blandford, Hildebrandt and Broberg, 2011). In recent years the area has gained significant traction, and a marked trend is noted from the literature, moving from an almost exclusively traditional 'error-centric' or traditional safety approach (a focus on 'what went/could go wrong') to also consider the RE perspective, which instead places more emphasis on positives; what works well and what serves to avoid or minimise adverse outcomes, poor performance and/or error.

As noted by Hollnagel, it is only "…in the early 2000s when resilience engineering was proposed as an alternative (or as a complement) to the conventional view of safety" (Hollnagel, 2016). Given the relatively recent emergence of the term, it is not unreasonable to postulate that a formal and widely accepted singular definition of RE has yet to be fully cemented. Perhaps the closest thing that exists to this in the literature is provided by Hollnagel, whose 2006 book titled *Resilience Engineering: Concepts and Precepts* (Hollnagel, Woods and Leveson, 2006) is often credited as the seminal text that established the field. Within it, the definition of resilience is as follows:

> "The essence of resilience is therefore the intrinsic ability of an organisation (system) to maintain or regain a dynamically stable state, which allows it to continue operations after a major mishap and/or in the presence of a continuous stress."

While as noted, the text within which this definition can be found is often considered a foundational work within the field, the above definition is rarely cited

today. Even its authors have since moved away from it, refining it substantially in subsequent publications, a process that Hollnagel himself discusses at more length elsewhere (Hollnagel, 2016). The refined and current iteration of this definition, which has appeared in subsequent publications (Hollnagel, Paries, Woods and Wreathall, 2011; Hollnagel, Braithwaite and Wears, 2013) describes resilience as:

> "The intrinsic ability of a system to adjust its functioning prior to, during, or following changes and disturbances, so that it can sustain required operations under both expected and unexpected conditions".

This current definition, though described elsewhere by Hollnagel himself as "…probably not the last and final one" (n.d), invites much interpretation on the part of the reader, reflecting the scope of the term and the diversity of circumstances within which it has been used. Given this broadness, it proves a useful exercise to unpack some of the nuances and potential complexities that are introduced by the definition.

Revisiting this definition in a recent text, Hollnagel, Braithwaite and Wears (2013), for example, highlight how:

> "This definition emphasises the ability to continue functioning, rather than simply to react and recover from disturbances, as well as the ability to exploit opportunities that arise, rather than simply survive threats"

If one conducts a closer reading still, further aspects are tacitly raised. For example, in explicitly describing how resilience could be seen to occur "*prior to, during or following*" a threat, a 'temporal dimension' is introduced, which is explored in Chapter 2.3.3 below (and which forms the basis for work described later in 5.5). The 'threat' itself is rather referred to as a "*change or disturbance*" and the reference to both "*expected and unexpected conditions*" reflects the fact that resilience occurs not only in the presence of failures of great magnitude (several

other resilience definitions imply this, as is discussed later in Chapter 2.3.6) but also in more regular circumstances. Moreover, the use of the term 'system' to describe the resilient agent can equally be taken to mean technical or sociotechnical system, an ambiguity indirectly acknowledged by Hollnagel et al. (2013) when they describe the need to confront "puzzles" such as a "system of systems".

Hollnagel et al. are of course not alone in proposing a definition for resilience in an engineering or systems safety context. Boin, Comfort, & Demchak (2010) offer an alternative definition of resilience which reflects how resilience can be seen to occur within a variety of entities, where they describe resilience as:

> "...the capacity of a social system (e.g. an organisation, city, or society) to proactively adapt to and recover from disturbances that are perceived within the system to fall outside the range of normal and expected disturbances"

Although Boin et al. specify a system being 'social' in nature in the above definition, one could easily adapt the definition as stated to include technical or wider socio-technical systems, or indeed it could further be taken to describe individual operators or actors within a system. The extent to which resilience can be taken to apply across different levels of granularity, ranging from high levels such as Boin et al.'s society and organisation, down to 'systems' (e.g. Hollnagel et al.) and further still to small teams and individuals (e.g. Back, Furniss and Blandford) is discussed in Chapter 2.3.1.

Another noteworthy point about the Boin et al. definition is that it introduces the notion of resilience having a somewhat 'proactive' nature, and this proactive quality is seemingly something that appears in many grounded examples of resilience. The assertion that resilience is by definition proactive however could be seen as overly restrictive, and this is potentially a point of contention, as further discussed in Chapter 2.3.7.

Elsewhere in the RE literature, a number of further definitions have been proposed which apply the concept in a variety of ways and at a variety of levels;

from post-event disaster response at a system-organisational level to proactive error-avoiding strategy formulation at an individual level. We explore this diversity and discuss further examples of definitions below.

2.3 Complexities and Dimensions Surrounding the Study of Resilience

While the concept of resilience has proved sufficiently malleable to be applied in a variety of ways, even within the confines of an engineering context, this flexibility does however come at a price. There still exists an inherent ambiguity with regards to the definition and scope of the term, and one might argue, a lack of consistency in how it is understood and subsequently applied.

As noted, resilience can be seen to occur prior to, during or indeed immediately after adverse events, and can be referred to as being in the system or organisation, in the individual or even in the device or interface. Additional contentions arise as one reads further into the literature, challenging for example the point at which resilience 'ceases to be' and merely becomes routine practice or standard operating procedure, and the frequent assumption that adverse conditions or consequences must be of a *significant* or *extreme* nature in terms of scale or severity. One can therefore conceptualise resilience in a number of different ways, and across a number of dimensions.

Given that the variety of ways the concept is presented is seemingly so disparate, the task of constructing a literature review of the topic with a cohesive narrative has been challenging. However as both a means to frame this discussion, and to situate works within the wide space of the RE literature, the remainder of this portion of the literature review is presented in terms of a number of 'dimensions of resilience', a choice of format and undertaking that has not seemingly been presented within the RE literature thus far.

These dimensions have been derived from a comprehensive review of the literature focusing on resilience engineering and the explicit study of resilience in a systems, engineering or design context. The review was conducted by searching for

key terms (such as ‘Resilience Engineering’ or ‘Resilience + HCI’) in several online databases for research publications, and from the bibliographies or reference lists of a small number of resilience engineering textbooks and key highly-cited papers within the field. The dimensions specified here were extracted from this literature by carefully considering and articulating some of the subtle differences in how resilience is conceptualised, and apparent ambiguities particularly with regards to explicit definitions of resilience across the publications consulted. While not exclusively constrained within this space, the review was also targeted towards work relevant to the resilience of individuals in particular, adopting a focus that has, to date, seemingly been largely overlooked within the existing literature. As will also be noted, the establishment of some of these dimensions has played a pivotal role in directing and informing the subsequent work later described in this thesis.

2.3.1 The Granularity Dimension

The majority of references to resilience in the RE literature consider the concept as an attribute of an organisation or system. Although this perspective is often taken, resilience is not exclusively framed in these terms and is increasingly being considered as a concept which scales down from high level sociotechnical systems, to groups and small teams, and further still to an individual level. As an illustration, resilience could, for example, be considered in (i) the way in which emergency services respond to a large-scale incident (high level systems resilience) and/or (ii) in the way resources are allocated by a team of dispatchers (the resilience of a small team of actors within the system), and/or (iii) in the way in which an ambulance driver may for instance use conscious foresight to select a longer but faster or less traffic-prone route when moving to an objective (resilience demonstrated by an individual through the implementation of a resilience strategy).

Back, Furniss, Hildebrandt, & Blandford (2008) discuss what might be considered as a fragmentation in the literature on account of these multiple levels of granularity. Back et al. describe how, frequently, investigations into resilience

consider the subject at one of these levels in isolation. For example, they demonstrate how from their own review of existing literature, a number of examples of work into resilience consider only organisational resilience, or the resilience of a small team within a specialised domain. While this naturally affords advantages in terms of depth and insight for producing findings that are readily applicable in a specific given context, it can be difficult to transfer or assimilate findings between these differently-pitched works and gain a coherent, integrated account of the study of resilience. Consequently, the RE literature faces challenges concerning how one investigation can build upon the next.

As part of their earlier work looking into resilience markers, Back et al. (2008) present one account of the different levels of granularity at which resilience can be observed, which is summarised in Table 1. Furniss et al. later discuss these levels of granularity in the context of a limited literature review of a number of recent investigations into resilience. It should be noted that the lists of 'Resilient Manifestations' are not exhaustive, but instead constitute only a representative account of some of the resilience mechanisms which can be observed across levels, and relatively independent of domain.

Back et al.'s account of the different levels of granularity at which resilience can be observed provides us with a useful means by which to situate individual studies and make sense of the otherwise somewhat fragmented RE literature, however their conceptualisation is not the only one. The idea of resilience existing at numerous abstract levels, and the implications of this, have also been discussed by others.

Granularity	*Examples of Vulnerabilities*	*Resilient Manifestations*
Individual Level	Errors in procedural routine	1. Reflection 2. Cue creation
Small Team Level	Coping with increased demand	1. Buffering 2. Work shadowing 3. Artefact use
Operational Level	High complexity	Error recovery
Plant Level	Plant shut downs or failures to start up, major accidents	1. Plant safety record 2. Response to major disturbances
Industry Level	Political and regulatory intervention	Performance necessity and availability of alternatives

Table 1: Levels of Granularity for Resilience (Adapted from Back et al. 2008)

Jeffcott, Ibrahim, & Cameron (2009) for example consider resilience to exist at three, perhaps broader, interconnected levels, which they describe as:

> "(1) the individual or cognitive/knowledge-based— for example, speaking up about safety fears;
> (2) micro-organisational or team/intergroup dynamics— for example, clear supervision, leader- ship and feedback; and
> (3) macro-organisational or whole organisation— for example corporate commitment to safety"

Jeffcott et al. go on to describe how resilience can therefore be seen as both "…a property of individuals as well as teams within their workplace…". Crucially, this work (as with the aforementioned account proposed by Back et al.) demonstrates that resilience is a concept that extends beyond the rather broad notion of a 'system', despite the prevailing usage of this term within the majority of definitions of RE.

The mere fact that resilience does apply across these levels does inherently present some challenging implications however. Stemming from this, there is some conceptual ambiguity as to the extent to which certain practices or behaviours may

or may not constitute resilience- for example should a routine checklist be incorporated as part of standard procedure, an individual who complies and adheres to such a checklist is probably not by conventional terms displaying resilience at an individual level (merely following standard operating procedure), even though the resilience of the wider system may be improved. This observation may appear spurious however it could be said to introduce implications regarding how best to go about increasing resilience or facilitating/accommodating it into the designs of systems, a notion discussed below in Sub-Chapter 2.3.5. The concurrent existence of resilience across levels of granularity can also introduce complexities when resilient practice at one level potentially impacts resilience at a higher or lower level, an observation which is discussed later in 2.3.8.

2.3.2 The Abstraction Dimension

The extent to which discussion about the concept of resilience also transcends levels of abstraction initially appears somewhat married to the above dimension of granularity. After all, it is noted for example by Furniss, Back, Blandford, Hildebrandt, & Broberg (2011) that one of the challenges of making sense of the resilience literature is the tendency for the manifestations of resilience to be more high-level and abstract as the level of granularity increases. Instances of resilience, for example at a sociotechnical system or organisational level, are innately more 'high level' than observational accounts of individuals' behaviour, owing to their need to span a broader array of contexts and settings. From a close reading of the RE literature one notes that, as much of the existing work in RE focuses on higher levels of granularity, so too the vast majority of established work is presented at higher levels of abstraction.

One oft-cited conceptual framework within the field of RE is Hollnagel's (2009) *Four Cornerstones of Resilience Engineering* as displayed in figure 2.

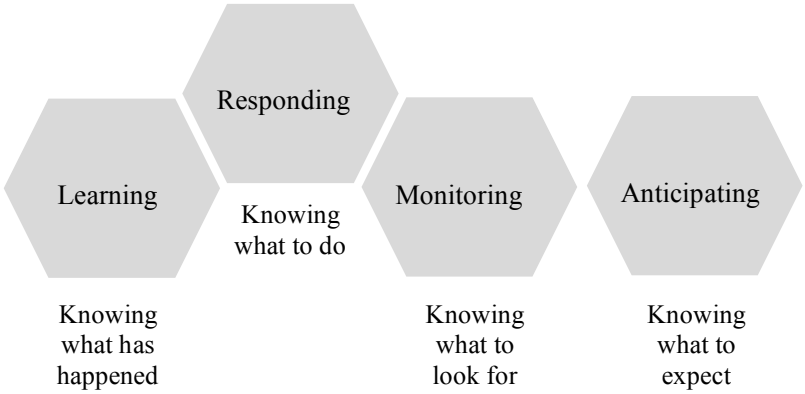


Figure 2. Hollnagel's Four Cornerstones of Resilience (adapted)

The four cornerstones of *learning*, *monitoring*, *responding* and *anticipating* comprise essential capabilities that Hollnagel attributes to the ability of a *system* to be resilient. While the authors go on to describe how this framework can be applied within the context of sociotechnical systems, its' relatively high level of abstraction could be said to enable only limited insights in terms of the concrete behavioural instantiations of individual actors in terms of depth or detail. That is to say, the structure afforded by the cornerstones as a means to analyse instances of resilience appears to possess more value when considered in the context of broader systems than at an individual-behavioural level, where its higher level of abstraction is less well suited to illuminating the more fine-grain aspects of human performance. This is a point noted by Furniss, Back and Blandford (2012) who discuss how improvements need to be made in establishing 'vertical traceability' between such high-level principles, and the more grounded observable strategy instances through which resilience is achieved by frontline operators.

This same limitation applies equally to some of the other conceptual frameworks in RE, for example that presented by Madni and Jackson (2009) as well as the limited repertoire of resilience-related tools such as Functional Resonance Analytical Modelling or *FRAM*, as described by Hollnagel (2012). This work offers useful accounts of resilience at a higher level of abstraction, however the concepts at play do not translate well to concrete instances at lower levels of abstraction, making

it hard for investigators or practitioners to extract insights from such frameworks at a behavioural-strategy level of abstraction.

This is an observation also noted by Furniss et al. (2011) who propose the *Resilience Markers Framework* as a means to explore how resilience can be 'traced' from high-level and seemingly abstract principles down to the grounded, observable and tangible accounts of resilience on the front line. Their framework is represented in figure 3.

The resilience markers framework considers episodes of resilience at three broad levels of abstraction; (i) high level *markers* which are highly generalisable across contexts and will usually correspond with a higher level of granularity (ii) the *strategy* level at a medium level of abstraction, which is further expanded on as detailed below, and (iii) low level *observations* which describe the tangible and concrete manifestations of resilience, often taking the form of individuals' resilience strategies.

As noted, Furniss et al.'s framework further expands on the mid-level strategies by identifying four elements which serve to guide analysis, comprising of the four labels in the central portion of figure 3. These stimulate reflection in turn on: (i) the repertoire of strategies, skills and competencies present in a system, (ii) the manner in which the system is operating, (iii) the constraints which hamper or conditions which enable resilience, and (iv) the vulnerabilities and opportunities that are a feature of the threat or disturbance which elicits a resilient response.

The resilience markers framework provides a useful lens with which to analyse episodes of resilience in a more holistic manner, linking concrete observations to more highly abstract phenomena. When it comes to more targeted and specific analysis of concrete instances of resilience at an individual level (i.e. resilience strategies), the framework does however again provide only limited support for detailed analysis of the mechanisms and motivations that underpin individual strategies.

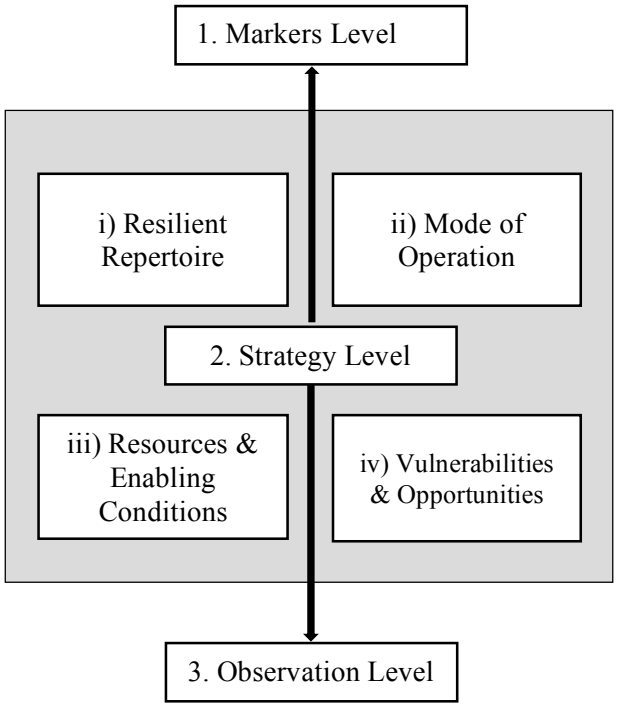
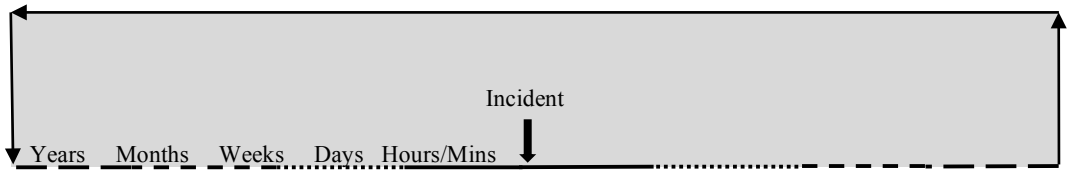


Figure 3. The Resilience Markers Framework (Adapted)

2.3.3 Time and the 'Moment of Resilience'

Broadly, where resilience is heightened within a system or organisation, at least one of two outcomes are presumed to result; reduced risk/vulnerability and/or increased recoverability/coping. Resilience could thus be considered as reactive versus prospective, referring to whether the resilient episode is said to occur after versus before the threat or disturbance. Typical frequently cited examples of resilience such as disaster response or risk assessment and strategy formulation serve to reinforce this distinction and generally fall on either side of this divide, leaning either towards anticipatory adaptive capacity, or recovery and 'coping' with the aftermath of an incident or adverse event that has befallen the system in question. That is not to say some references cannot be found to resilience happening during or at the moment of disruption (as opposed to 'after' it), however this can debatably still be framed in a reactive way owing to such phenomena still occurring in response



Type of Res.	Proactive		Reactive	
Agents of Res	Designers	Operators/Users		Investigators
Mechanism/ Marker	Workload balancing	Creativity	Organisational learning	
Threat	Erosion of Safety	Initiating Event	Consequences	
Goals of RE	Preparedness	Mitigation	Compensation	Developing New Practice
Means	Design for Res.	Support Improvisation		Incident review

Figure 4. Hildebrandt's Resilience Timeline (Adapted)

to, or being triggered by the presence of an adverse event. This does however become less of a straightforward dichotomy in some cases, for example when such a threat or adverse situation persists over a duration of time, as discussed further below.

Hildebrandt, Broberg, Massaiu, Dhillon, & Tarasewicz (2008) present one conceptualisation of the variation in timescale which is present across resilience in their *Resilience Timeline* presented in figure 4 above. Hildebrandt et al. discuss the concept in terms of 'preventative resilience' and 'recovery resilience' depending on where, in relation to an 'initiating event' (incident or accident) the instances of resilience manifest. The timescale extends in each direction from the initiating event, meaning instances can be plotted in the seconds, minutes, days, months and years preceding or following the initiator. This represents one tangible way to situate different instances of resilience and has been presented as a tool to facilitate discussion of resilience, particularly in the case of practitioners not already familiar with the concept, for whom the broad and high-level definitions of the term and ambiguity towards timing, Hildebrandt et al. suggest, can be problematic.

Westrum (2006) also discusses at some length how the temporal dimension of resilience in relation to a threat/incident/initiator is fundamental to how one perceives and makes sense of the concept. Indeed, Westrum's proposed definition of resilience refers directly to this aspect:

"…Resilience thus has three major meanings.

- Resilience is the ability to prevent something bad from happening,
- Or the ability to prevent something bad from becoming worse,
- Or the ability to recover from something bad once it has happened"

Regarding anticipatory resilience, Westrum describes how the ability to 'foresee and avoid' can itself be considered broadly in terms of (i) recognising and responding to "…learning the lessons of experience" as well as (ii) "…foresight that is associated with the processing of 'faint signals'", which loosely equates to the perception and pre-emptive addressing of potential, previously unexampled events.

An assertion which is perhaps somewhat deemphasised in Hildebrandt's Resilience Timeline is presented by Westrum- the consideration of resilience at the precise time of the threat/incident. As noted, if one is to consider resilience purely in terms of being prospective/anticipatory verses reactive, then the distinction between a resilient instance occurring during a threat window versus after it is not immediately pronounced; in each case the resilience is responsive. However, in presenting the notion that resilience can occur *within* a threat window, and that this is a fundamentally different premise to resilience occurring after it, Westrum does acknowledge a temporal variance in the nature of threats/incidents. Two of his examples of 'concurrent' resilience for example are strategic innovations during World War II, and they capture a responsive quality that is not so concerned with recovery, rather more about improving ongoing performance during a protracted period of adversity. These examples serve to demonstrate that the conceptualisation of an initiator as being a single, clear-cut event may in some cases potentially represent an oversight or indeed oversimplification; the nature of the threat or

disturbance which forms the target of resilient intervention is not fixed, and there is consequently potential merit in considering resilience not only as 'before' and 'after', but also 'during'. Relating somewhat to this, the nature of the threat or disturbance in terms of scale is further discussed below in 2.3.6.

2.3.4 Originality and Absorption into Routine or Standard Practice

When considering precisely what resilience is, another issue that arises concerns originality versus recurrent use, and integration into common practice. While this aspect of resilience may not constitute a 'dimension' in the same way as the previous examples, we posit that it still forms a fundamental complexity which shapes one's interpretation of the concept.

Furniss, Back, & Blandford (2010) propose drawing a distinction between instances of truly novel and creative resilience (i.e. *formulating* some type of resilience strategy) which they refer to as 'Big R', versus instances of resilience during which previously established exemplars of resilience are reused or adapted, which they term 'little r'. Where a resilient strategy or technique is deemed to be highly effective or successful, a natural assumption may be recognition and reuse of the strategy. One could probably attribute any number of steps in checklists or aspects of now common practice to have originated from the intuition of individuals operating in a resilient capacity. However, when one ends up merely to be adhering to instruction and following standard operating procedure, the extent to which they could be considered to be themselves demonstrating or practicing resilience is perhaps contestable.

The question arises from this: whether (and indeed where) a once novel and effective resilient strategy ceases to be what we recognise as resilience, as it becomes incorporated or absorbed into a routine practice or operation. Dominic Furniss summarises one potential perspective on this:

> "I think we say in a paper that Big R is most clearly identifiable as resilience. It seems to me that little r is important too as these mechanisms are shared. However, we have deemed resilience to be 'out-side design basis' which means that when these strategies are designed in, and hardwired into the system, then it is no longer a study of resilience major - it might be design or safety or something else"
>
> *(D. Furniss, personal communication, March 16th, 2012)*

The above however summarises only one viewpoint, and one might alternatively assert that (i) there is a fine line between 'little r' resilience and the kind of 'non resilience' that falls outside design basis, and/or (ii) resilience could be said to have 'shifted up a level' i.e. even if 'local' resilience no longer occurs at the point of interaction, there has been a net benefit in higher-level system resilience, thus it is still beneficial to consider the concept. Indeed, for practitioners who consider resilience exclusively as a high-level attribute of a sociotechnical system, any contribution at an individual level that promotes and increases resilience might be taken as resilient action, even if it is something as trivial as following a predetermined checklist.

Returning to the discussion of how resilience relates to design, one could postulate that since the boundaries of the 'design envelope' are not fixed, the issue could be said to become hypothetical or semantic. However, it remains clear that resilience exists across a scale of 'novelty' and this has implications when one comes to define and scope the term.

2.3.5 Embedded Device or Task Resilience

Related strongly to the notion of resilience becoming absorbed into the working practice of a system is the way in which resilience can be conceptualised as becoming embedded into device design (e.g. through interventions in its interface) or

even a task. Ann Blandford provided one very apt example of how resilience can seemingly be 'shifted' from an individual strategy to a system or interface feature:

> "Until the latest version of *Thunderbird* [1], I had developed a personal resilient strategy of always attaching any attachments before composing the message, to reduce the likelihood of forgetting the attachment. In the latest version, an explicit reminder has appeared in the mail window as soon as I typed the word "attach", and it won't let me send the message until I explicitly confirm that there isn't meant to be an attachment. So the resilience has moved from being a personal strategy to being designed in to the tool, making it a "safer" tool."
>
> *(A. Blandford, personal communication, March 16th, 2012)*

As noted, this appears strongly related to the notion of resilience becoming ingrained in routine or common practice, although the boundary here indicating resilience has shifted from being a personal strategy into something else is evidently more explicit. The example above illustrates however that the issues or threats which individuals address and overcome through implementing resilience strategies can, once articulated and considered, sometimes be addressed through relatively straightforward technical intervention. Although in the case described here, the instance of resilience (i.e. the behavioural adjustment of changing working patterns) is not itself 'designed-in' to the system, rather the system becomes more resilient to error through an alternative intervention (an on-screen prompt serving as a visual cue) which addresses the same problem (a memory slip error on the part of the user).

Similarly to the above, a limited pool of literature discusses how resilient principles can be deliberately designed-into interactive tools and systems. Within the domain of healthcare, Nemeth & Cook (2009) provide one example of this in their

[1] A desktop email application

outline of a conceptual design for an *infusion device*[2] that places a greater emphasis on the context of a patients' situation. Nemeth and Cook describe how the recent course of a patients' treatment provides invaluable contextual information which could potentially avert some of the common errors in administering medication (i.e. errors of omission or repetition) however this information is not available on existing infusion devices. Their proposed design thus makes the interaction more resilient against the threat of incorrectly administering medications through the graphical display of a patients' progression through an infusion, providing a 'glanceable' means by which to ascertain progress, and in turn reducing the potential for error.

While the increased functionality (contextual display) described by Nemeth and Cook is explicitly motivated by an increase in resilience, one cannot escape that resilience, once incorporated into concrete design, seems a far-removed phenomenon from the kinds of resilient strategies observed in situ. Resilient actions undertaken by frontline operators are often by their very nature removed from, or outside of, design-basis as previously discussed. As Nemith and Cook describe, 'resilience' can be used as a motivation for the inclusion of new features if designers are mindful of it and of the potential issues and weaknesses a prospective system faces, but the very nature of resilience often implies unforeseen or unanticipated circumstances (certainly in the case of reactive resilience) which require resilient action. One can draw a distinction between the goals of 'designing resilience in to a system' versus 'designing a system that better accommodates resilience', although both are a means by which to produce a more resilient system. The work described in this thesis moves towards the latter of these goals, however one cannot neglect or omit discussions of the former.

[2] A medical device designed to administer substances intravenously

2.3.6 Scale or Nature of the Threat or Disturbance

Another point worthy of considering when asking what constitutes resilience; as noted previously, the majority of instances of resilience reported in the literature are taken from safety critical domains where consequences of poor performance are of great scale. To put it crudely, 'getting it right' is of significant importance. Also noticed when consulting many resilience engineering definitions is an emphasis of significant scale regarding the disturbance or threat; two descriptions at least make reference to threats or disturbances as being of an 'extreme' scale (Tierney & Bruneau, 2007; Comfort, Oh, Ertan, & Scheinert, 2010) and numerous other definitions make reference to the threat or disturbance being of an unanticipated, surprising, or beyond design basis nature (Hollnagel & Woods 2011; Nemeth & Cook, 2007; Dekker et al. 2008).

Alternatively, others within the literature have broadened the scope of situations in which resilience arises, and recognised that resilience can occur in the case of more 'continuous stresses' (Hollnagel, 2008; Nemeth, O'Connor, & Cook, 2009) or both unexpected and expected conditions or situations (Hollnagel, 2011; Fujita, 2006). Westrum (2006) provides some discussion of how threats vary in nature, distinguishing between 'regular threats', 'irregular threats' and 'unexampled events'. The author, however, points out that resilience is a useful concept across cases spanning this variety of situations, as opposed to merely within the area of irregular or unexampled threats.

The nature (intended to be taken here as something more akin to 'expectedness') and magnitude of threat has implications with regard to resilience and is a common feature of definitions of the term, however another related but distinct variable which one might consider concerns the nature or significance of the domain in question. Recently, it has been noted that resilience can be observed in all manner of contexts which aren't necessarily of a safety critical nature, and in which threats or disturbances can be minimal (Buchanan, Back, & Furniss, 2011; Furniss, Back, & Blandford, 2011). Within the team of researchers looking into resilience as

part of CHI+MED, one often cited example of resilience at an individual-strategy level is a relatively common and simple behaviour of leaving one's umbrella propped up against the front door to minimise the risk of forgetting it on the way out. While such an example may seem trivial compared to many of the resilience case studies which make reference to major events or safety critical domains, the principle of perceiving a threat and then planning and executing a strategy designed to minimise the likelihood of the threat manifesting as an error is an undeniably resilient quality in this behaviour, despite neither the disturbance (a simple memory lapse) nor the consequence (leaving without an umbrella) being of critical importance or significant scale.

It is understandable that resilience has often been framed within the context of safety critical domains, where much has already been invested in terms of traditional safety or human factors work to, as far as possible, reduce the threat of failures or adverse events. Resilience in this case offers a fresh and complimentary perspective with which an improved level of safety can be obtained, and the potential benefits of applying RE in the context of saving lives clearly presents salient and invaluable implications. However, to frame resilience as a concept which is relevant exclusively in cases of severe risk or danger is perhaps overly restrictive- after all as has been demonstrated, certainly at an individual-strategy level, that resilience can arise in all manner of contexts. Potentially, value can be found in broadening the scope of resilience-focused work to include more mundane and everyday threats, responses and circumstances. One might at this point refer to an observation by Hollnagel who, when discussing his distinction between Safety I and Safety II (a topic discussed later in Chapter 3.3.2), points out there are an abundance of everyday instances of resilience which may be considered in addition to the relatively limited pool (in terms of frequency) of cases from safety critical domains. While there is clearly much value in the latter, one need not neglect the former, and arguably the fact that this has seen relatively limited exploration further legitimises it as a target for renewed investigation. Some of the work outlined later and conducted as part of this PhD adopts this perspective and considers resilience across a range of

'everyday' situations in an attempt to capture a broader selection of resilient behaviours and ultimately consider resilient principles and mechanisms at a level of abstraction independent from domain.

2.3.7 Resilience as Proactive, Intentional or Conscious

One potentially important aspect of resilience that largely seems to escape discussion or reference in the majority of definitions is the extent to which resilience is conscious, reflected-upon or articulated. Work conducted during the course of this PhD and outlined later reveals that individuals may deploy apparent resilient strategies or behaviours without explicit awareness. One example of this is where individuals are required to retain information in short term memory, for example a digit span task, some will utter items repeatedly under their breath utilising verbal rehearsal to assist working memory. We have observed instances of this where subjects appeared to be doing this idly or 'absent-mindedly', and were not able to report or articulate upon this behaviour even upon being specifically probed with regards to it.

The notion of resilience becoming 'automatic' in one's behaviour could potentially be seen as another manifestation of resilience becoming 'ingrained' into normal practice within a sociotechnical system as discussed previously in 2.3.5, however at an individual strategy level some of these resilient actions seemingly fall beyond the routine functioning of systems due to their becoming highly personalised. There is perhaps also less of a challenge in extracting and articulating these observable but 'subconscious' strategies, given they can be spotted directly by mindful third parties (e.g. researchers). Resilient steps that have become absorbed in complex or convoluted processes may still be more challenging to discern.

As noted, this precise notion seems largely unaddressed within the literature, however Back, Furniss and Blandford (2007) do present some relevant discussion on the topic in their conceptualisation of 'reflection in action' versus 'reflection on action' in the context of cognitive or individual resilience. Back et al. describe how

they see a distinction between the resilience attributable to reflection in action (which loosely refers to individuals reflecting concurrently while conducting a task) versus reflection on action (which refers to the retrospective consideration and reflection of past experience). Back et al. describe how there may be a difference in the kinds of strategies which are observable from each instance, however they do not explicitly reference how a lack of reflection (both concurrent and retrospective) might present implications for resilience.

The assertion that resilience can be observed in cases where it is not explicitly intended, could however be a contentious one. Much of the existing discussion surrounding resilience implies that resilience is an active and intentional phenomenon, and one definition at least (Boin et al., 2010, as previously discussed toward the beginning of the present chapter) makes clear reference to it as being 'proactive', which implies some degree of intent. However, it is clear that some of the behaviours which individuals deploy on the frontline which contribute positively to safety or performance are not necessarily consciously reflected upon, and such behaviours, while debatably not resilience at an individual-strategy level, do serve to improve wider resilience. Such behaviours could therefore still be seen as the kinds of 'resilient-esque' phenomenon that, like more clear-cut examples of individual resilient strategies, have potential value as a source for increasing resilient capacity higher up the chain of granularity, resulting in a net gain of resilience at a system-wide level.

We would posit that one can draw a distinction between what we will term as 'resilience strategies' – where resilience is intentional and conscious, and 'resilience behaviours' – where resilience is more tacit, and less reflected-upon. Working on this basis, we consider both to be within the scope of the current work as while there may be a subtle semantic difference between strategies and behaviours that contribute towards improved resilience, their functional consequence is alike. If the broad purpose of investigating an individual's resilience in HCI is to articulate lesser-considered activities that contribute positively to safety or performance, it seemingly makes little sense to artificially close the scope of this by actively

excluding ‘behaviours’ that do not conform to the intricacies of the ‘strategy’ definition, while being employed in the same situations and achieving the same ends.

2.3.8 Interactions Between Different Manifestations of Resilience

One interesting aside which seems also worthy of mention at this point is the fact that when resilience is considered as existing concurrently at different ends of a spectrum within a system, it becomes possible for actions to simultaneously contribute both positively and negatively to resilience. Take, for example, the following hypothetical scenario exploring the extent to which a workspace may be optimised through individual customisation.

Suppose a worker is afforded the flexibility to reconfigure their environment and introduce artefacts or cues which help them maintain or improve performance. The use of such strategies could improve resilience at an individual or ‘local’ level. However, should circumstances dictate that they must work from a new location, their reliance on resilient strategies and artefacts which have suddenly become unavailable illustrates how what might be considered a positive contributor to resilience may also introduce potential latent frailty. At a higher level of abstraction, one might also argue the capacity for an organisation to share spaces (e.g. move staff between desks) is a resilient property that is assisted by maintaining uniformity and consistency. Thus the adaptations and customisations that might constitute resilience for the individual could in fact erode resilience at a higher level of granularity.

Another example of resilience conflicting across levels of granularity was observed first-hand by the thesis author in a busy hospital ward where a frequently used corridor was obstructed by a set of locking doors (with swipe-card access that appeared temperamental and a source of frustration for some operators). In this situation, a member of staff was observed ‘pinning open’ a door using a fire extinguisher. Viewed through the lens of individual resilience strategies, this might be considered an instance of cognitive resilience depending on motivation- and indeed this did assist with the timely transit patients in the moments following. At a

local level, this seemingly trivial act could be said to have constituted a resilient intervention and may have contributed positively to performance, in so far as access was improved and patients were able to be transported more quickly.

However, if one were to take a broader systems perspective, in the above situation the action taken by the individual might have introduced risk and consequently had a net decrease on the resilience or safety of the system- both in terms of security or if, for example, a fire had occurred (owing to the removal of the extinguisher appliance from its location, and indeed pinning open of what may have been fire doors).

There are many such cases where improving 'local resilience' with some aspect of the system might come at the expense of, or conflict with, broader 'global resilience' in a system. The fact that 'shortcuts' in safety-critical work are often described as 'workarounds' and that the term (discussed later in section 3.4.1) carries heavily negative connotations is a reflection of this.

While this observation perhaps represents more of an interesting aside than an explicit target for investigation in the current thesis, if it serves no other purpose it at least demonstrates some of the complexities of studying resilience, and how it can be challenging to merely make a system, process or entity 'more resilient'. In some cases, the notion of treating resilience as a singular property emerging from a system could be said to break down, or at the very least becomes problematic. An important aspect of the targeted investigation of resilience down the line thus becomes exploring these potential unanticipated implications, and exploring the aspect to which a 'trade off' might have to be considered in some specific situations. For the purposes of this thesis and as later described in 3.5, we conceptualise resilience as being a positive contributor to the net safety or performance of the given scenario in which it is enacted, however the discussion here reminds us that in some contexts, the notion of how safety/performance is being improved at one level of granularity while potentially eroded at another, is a consideration one must be mindful of.

2.4 Resilience and the Individual

While there is an increasingly developed literature addressing resilience, as noted previously, a significant majority of this work targets a higher level of granularity than the individual/cognitive level. Investigations addressing system-wide resilience, resilience in teams or sociotechnical units, or generic device resilience are readily available and provide an insightful contribution into how systems or interfaces can promote enhanced resilience. In contrast, the literature on the resilience of individuals at the 'sharp end' and the tangible active interventions they utilise to manage threats is surprisingly scarce.

We recognise that this is in part an issue concerning semantics. Where resilient episodes are recorded and discussed in the literature, they are often termed or framed in a different way. For example, there are bodies of work addressing cues, checking, appropriation, task structure and management of interruption and other topics of varying degrees of relevance, and topics such as these are discussed in the following chapter. There are also numerous anecdotal accounts of resilient strategy use which are discussed within other contexts and not labelled as resilience (one such example being work conducted by Randell & Johnson described below in 3.4.1). There is on the other hand a limited body of work that exclusively addresses the analysis of the variety of resilient strategies and behaviours which one might observe at an individual level, which we present here.

As outlined previously when discussing the abstraction dimension, Back et al.'s (2008) investigation into resilience markers features discussion concerning how the concept of resilience scales down to an individual level. In this relatively early work, Back et al. focus on resilience as a means to specifically reduce cognitive slip based errors, such as errors of omission or mode errors, during routine tasks. The authors present the findings of a lab study which involved participants being subjected to a deliberately challenging and error-prone task paradigm (that is to say the task was designed to elicit both omission and mode-based slip errors), and the authors go on to provide some discussions as to the resilience they observed.

Regarding omission errors (specifically omission errors involving an 'initialisation step', the first step in a repeated sequential routine) Back et al. discuss how reflection assisted performance and made subjects more resilient to the specific omission error at play in their study. However, the authors do not make reference to reflection as being a strategy on the part of users, rather a variable in an interaction which should be encouraged by systems designers, for example through enforced lock-out periods (as explored further in Back, Brumby, & Cox, 2010).

In the case of the second deliberate error designed into their study however, Back et al. describe what does appear to be an active resilience strategy on the part of users which involved their placement of a mouse cursor at a certain position, and how this was seemingly used as an ad-hoc visual cue to assist attentional tracking. The authors conclude that both reflection and resilient strategy formation (in this case, personalised cue creation) are symptomatic of metacognition on the part of users, and this should, where possible, be encouraged by developers looking to improve resilience.

Buchanan, Back, Furniss and Blandford (2011) expand on the forms resilient strategies may take in their discussion of how appropriation can be linked to an individuals' resilience. Buchanan et al. describe cases in which a resilience strategy featuring appropriation may be deployed; the appropriation of a physical object to assist in administering medication (the examples being how a nurse might repurpose a cup as an attentional cue, or a privacy screen may be used to minimise the threat presented by interruption in a busy hospital ward) or the appropriation of music to support the task of attentive reading (through minimising the disruptive effects of distractions in the background). The discussions here have an important implication in that they hint at the potential breadth of resilient strategies which may be encountered; it is demonstrated that resilience can be about more than merely managing risk or reducing error in safety critical tasks. It can take numerous forms, across different contexts, and can be found even in everyday tasks or work.

Recent work by Furniss, Back and Blandford (2012) further discusses the variety of resilient strategies and behaviours which exist at an individual level, and

for the first time an attempt is made to articulate and catalogue the 'types' of strategies that exist. Furniss et al. describe how one fundamental current issue with the investigation of resilience at an individual level is the lack of a vocabulary or established framework for the analysis of such cases. The authors make the first steps towards addressing this and establishing a foundation for the analysis of individual resilience by collecting a pool of resilient strategies using brief self-reported accounts of resilience strategies captured on Twitter, and analysing the content of entries, grouping them into a number of categories containing common themes. Furniss et al.'s categorisation scheme is presented in Table 2.

This categorisation scheme helps to articulate several classes of resilient strategy that are otherwise largely absent from this specialised area of the literature (e.g. pre-emptive separation and disambiguation). However, the authors concede that this list is not exhaustive and that some of the categories are "at different levels of abstraction and overlapping in places". Furthermore, the authors note limitations in the dataset in terms of the number of unique contributors (n=5) and the length of entries permitted (at 140 characters, a limit imposed by the adoption of Twitter as a means to collect data). Still, crucially this work provides us with a form of foundation (if only in the form of a working vocabulary) with which to frame and make sense of otherwise merely anecdotal accounts of resilience, and offers a first true insight into the variety of resilient strategies that exist at an individual level.

Category Title	*Description*
Cue Creation to Support Prospective Memory	…Where someone might create a cue to remind them about something that they are likely to forget… Cues might be inanimate (like a bookmark) or may include the activity of agents such as alerts from devices and other people.
Premature-completion Awareness	…Facilitate someone remembering some action or thing when the main goal of the task has been achieved – often to avoid a post-completion error… This looks like a sub-class of 1: Cue Creation.
Pre-emptive Separation and Disambiguation	…Where someone perceives a threat in mixing things up later in a process so they take action to: 1) separate different streams of information or physical things that might get mixed up in a task; or 2) to differentiate and disambiguate signals e.g. labelling keys on a bunch to differentiate them.
Pre-commitment Check	These are strategies where someone will check that they have the right information or the right equipment before committing to a task or proceeding through a critical step.
Managing Resource Availability	…Where someone takes action to make sure that they have resources available to them to act. These resources could be physical items or pieces of information. Rather than helping the person remember, this strategy will compensate for forgetting; e.g. a person could have redundant resources in different places so that forgetting is no longer an issue.
Routine Adjustment	These are strategies where someone perceives a potential threat or opportunity and changes their behavioural routine accordingly.
Reinforcement	These are strategies where someone uses their initiative to reinforce some safety barrier, procedure or practice e.g. perhaps they can see it eroding or that it's weak so they take initiative to reinforce it.

Table 2: Furniss et al.'s Categorisation of Individual Resilience Strategies

As noted, the body of work which specifically targets the resilience strategies of individuals is currently far from developed and comprehensive. It is this specific topic that the current thesis addresses. However also as noted above, one issue with the study of resilience strategies is that a number of other relevant bodies of work address aspects of this topic, however adopting different approaches and utilising alternative terminology. The following chapter introduces some of this broader literature, both in terms of broad, high-level subjects that are relevant to the study of resilience, and later in terms of more specific concepts that either could serve to directly inform our study of types of strategy, or that even constitute types of strategy themselves.

Chapter 3: Literature Review II:

Framing and Contextual Literature

3.1 Chapter Introduction

As described in the opening chapter, the intention of the current thesis is to better understand how users develop and deploy strategies to enhance their resilience, primarily in terms of operating interactive devices. While Chapter 2 above presented an account of the literature directly addressing the concept of resilience and the discipline of Resilience Engineering, such an account of these topics alone does not provide sufficient insight given the objective of the current work. Much of the RE literature for example extends beyond a level of granularity and abstraction that is immediately applicable within a localised, HCI-relevant context. At the same time, there are important concepts from a variety of additional and broader literatures that are also useful to consider. The current chapter seeks to address the latter of these points by exploring this supporting and contextually relevant literature.

Owing to the safety critical nature of healthcare (and its contextual relevance in the current PhD), and to the inherent relationship between safety and resilience, a brief account of the traditional literature on safety and the study accident investigation is initially presented. A summary discussion is then provided which introduces and situates relevant work within the fields of human factors and the study of how people perform tasks and conduct work in a broader sense, including summary presentation of the analysis and modelling of human performance, the types of errors people make, and the role of memory and attention in HCI. Closing this chapter, we revisit the notion of resilience strategies as previously discussed in Chapter 2, and introduce a number of discrete but interrelated topics spanning work from other disciplines, but which are particularly pertinent for the topic of resilience strategies and which may indeed constitute resilience in some cases.

3.1.1 Scope of Literature Presented in Current Chapter

With regards to the scoping of the literature review, in the first portion of the review, presented in Chapter 2, this was a relatively straightforward undertaking (i.e. work explicitly addressing the topic of Resilience in a safety/systems context, with a focus on HCI-centric investigations or work directly targeting the actions of frontline operators, as described in 2.1). Determining the scope of this second portion of the literature review has however proved more challenging.

While existing work in the field of Resilience Engineering provides a useful context in grounding the current thesis topic, as discussed in Chapter 2, investigation of strategies and behaviours to enhance resilience represents only a small portion of this existing work. Similarly, we have noted that there are a range of topics that, while not explicitly or exclusively addressing resilience, can be leveraged to inform the study of resilience strategies and behaviours. Topics such as the study of safety, the study of human error, and the investigation of human performance represent clearly related concepts, as evidenced by the frequent references to each within the Resilience Engineering literature. The collection of concepts we have explored in 3.4 below, such as workarounds, task-restructuring and appropriation, were also derived from the resilience literature, in particular the early efforts to study resilience at an 'operator' level (principally by Furniss, Back and Blandford, 2012, and Rankin, Lundberg, Woltjer, and Hollnagel, 2014).

With regards to the depth of coverage for these areas, the topic of study for this thesis is at a cross-section between a number of expansive, established bodies of literature (predominantly safety science, psychology and human computer interaction) and to provide a comprehensive account of each would extend far beyond the remit of the current investigation. This chapter therefore necessarily represents a 'mini-review' (as described by Pautasso, 2013) of these topics, with concepts for inclusion selected based upon their perceived relevance to the topic of resilience strategies or their historical influence in shaping our understanding of their respective fields. Owing to the iterative composition of this review, some topics have

also been introduced (e.g. 3.4.5) or expanded (e.g. 3.4.1) retrospectively as a result of observations from our studies.

3.2 The Study of Safety and Accident Causality

Safety is typically presented as freedom from harm, danger or unacceptable risk. The study of safety has an extensive history; indeed, we have most likely considered safety in some capacity for as long as we have been aware of potential threats or dangers. Discussion regarding safety can be problematic however, owing to the diversity of threats which exist in any given context, and the numerous factors impacting and affecting safety. Our understanding and traditional perspective on safety is at the same time fundamental to the emergence of the resilience perspective, thus a brief account of some of the seminal work on safety is presented here.

One initial interesting point to consider when discussing safety, as noted by others (Hollnagel, 2012; Reason, 2008) is that safety is typically discussed in terms of its absence rather than its presence. We have traditionally invested far more in investigating cases where safety was lacking (i.e. accidents, incidents which resulted in negative consequences) than we have in targeting the existence or resulting outcomes of safety (or the *presence* of safety) per se. This accounts for why the following models, while seminal works in the field of safety, explicitly target accident causation and contributory factors, as opposed to the presence of safety itself, and the implications of this are further explored toward the end of this chapter.

3.2.1 Classical Models in Safety

An important early account of accident causation is described by Leveson, Stringfellow, & Thomas (2009) who discuss the 'domino' model (figure 5) originally by Heinrich (1931). The model posits the existence of five primary factors comprising: (i) the social environment (ii) the fault of a person or persons (iii) unsafe acts or conditions (iv) resulting accidents and (v) injury or other adverse outcomes. The central notion is a causal and linear relationship between these factors, which is

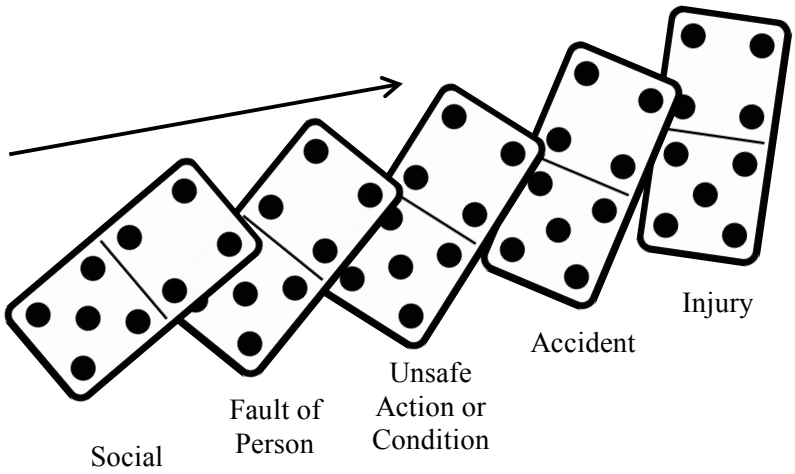


Figure 5. The 'Domino' Model

likened to the toppling of a chain of dominos. The model implies the popular but contentious notion of a 'root cause' for all accidents, and infers that one can, with sufficient understanding and appreciation of the aforementioned factors, trace the causal links back and intervene to reduce or eliminate the risk of repeated accidents.

The model can be commended for its memorable and easily graspable metaphor, and its emphasis on human error as a contributory factor in the causation of accidents (which was seemingly largely overlooked prior to Heinrich's model). However, while the model has proved to be an influential contribution in shaping our early understanding, and indeed much subsequent related work, it is now often considered somewhat reductionistic (Leveson et al., 2012) and indeed overly deterministic (Hollnagel, 2012).

An alternative and more recent account of safety conceptualises interventions to improve safety or reduce risk as *safety barriers*. This approach represents a broader perspective rather than a single specific model, and the absence of a universally agreed definition or "well accepted barrier theory" is noted (Sklet, 2006; Schupp, Smith, Wright, & Goossens, 2004). Generally, however, barriers are taken to shield targets (individuals, systems, organisations) from continuous threats or hazards (which may take a wide variety of forms dependent on context) that would otherwise result in an accident or adverse outcome. Thus safety is achieved when

one or more barriers functionally deter or eliminate the risk presented by threats, while accidents are proposed to result from the lack of sufficient or adequate barrier safeguards. There appears little consensus on what precisely constitutes a barrier, however Sklet (2006) notes a distinction in some of the literature is drawn between barrier functions (which describe the functional purpose of barriers) and barrier systems (which constitute the interaction of multiple components in realising the implementation of a barrier function).

One related model worthy of brief mention which expands on this notion of safety barriers is the 'bow tie' model as described by Ale (2009). This expands the concept to consider not only the risks associated with the causes and contributions towards accidents, but also the implications in terms of consequences and resulting action. Figure 6, shows causal and contributory factors on the left in addition to a number of barriers as labelled. The dashed-line in the very centre of the diagram represents the point of an accident occurring, while the 'branches' in the tree-like diagram indicate preceding or subsequent implications or courses of action. Should one or more threats defeat the barriers and culminate in an accident there is still opportunity for additional barriers to the factors contributing towards adverse outcomes, represented by the barrier labelled on the right of the diagram.

The important implication of this model is its' suggestion that barriers can address not only frailties or risks in the 'build-up' to an adverse event, but can also be deployed reactively to minimise the risk of subsequent harm or loss in the eventuality of an accident or adverse event. This clearly has implications when one comes to consider resilience, and in particular the 'timeline' of an accident or adverse event, and these notions of actions being taken both prior to, and in response to, a triggering event are something we will later explore more closely.

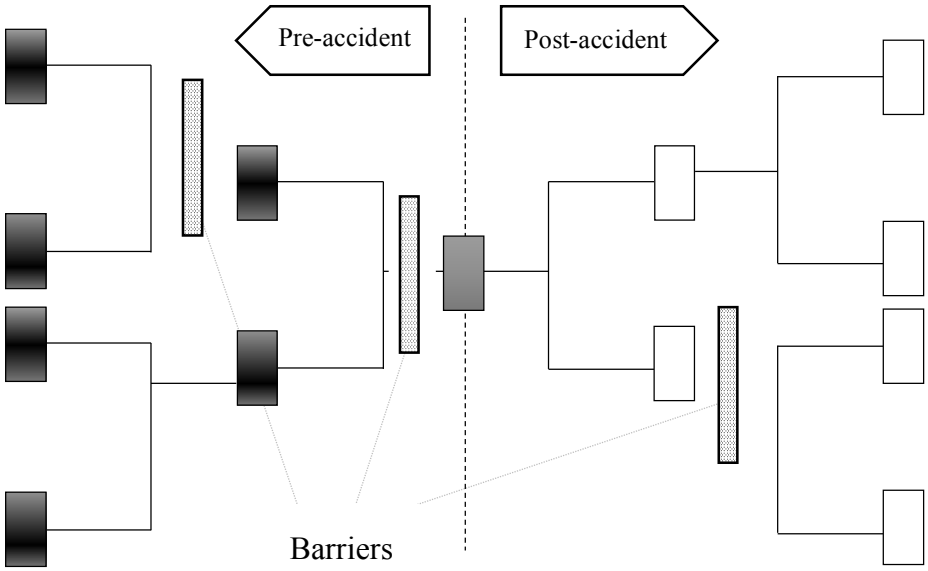


Figure 6. The 'Bow Tie' Model

Another equally interesting and valuable extension of the safety barrier perspective is provided by James Reason in his influential and widely cited *Swiss Cheese Model* of accident causality (the development of which is succinctly described in Reason, 2008). The model draws an analogy between the numerous barriers defending a target from threats or risks, and multiple slices of Swiss Cheese, each with holes representing frailties or gaps in the effective functioning of a barrier. Reason stipulates that these holes, the potential results of either active failures or latent conditions, are liable to open, close and shift through the normal course of operation. Owing to the presence of multiple barriers, these latent conditions or momentary failures alone may not be sufficient to lead to an adverse outcome, however there are occasions when the holes in these multiple 'slices' align to allow the trajectory for an accident to penetrate all the barriers simultaneously, it is then we witness accidents and subsequent harm or loss.

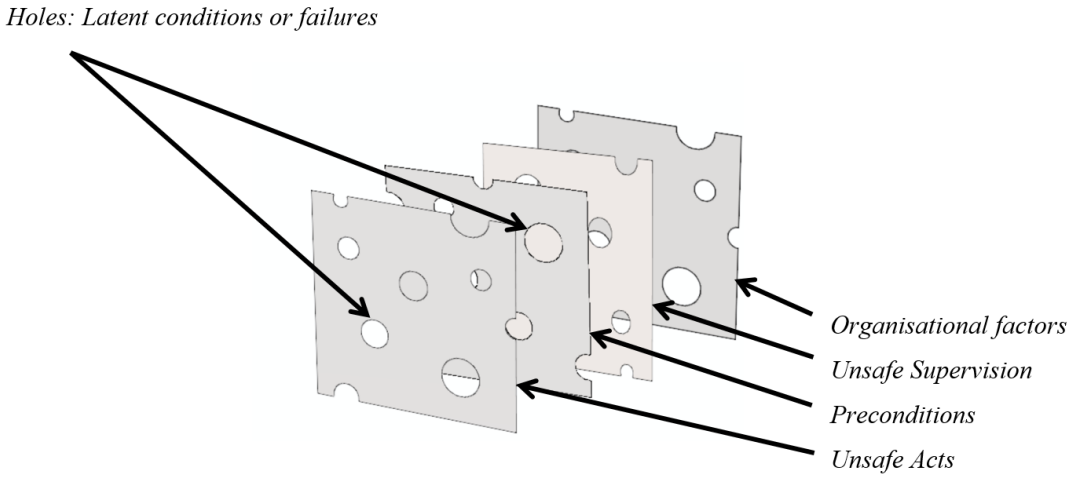


Figure 7. The 'Swiss Cheese' Model (Adapted)

It is worth noting, however, that while the Swiss Cheese model is widely discussed and has been applied to a wide variety of domains (Reason, 2008), the model still implies a linear notion of causality based upon fixed relationships between system components, and is subsequently still considered by some as insufficient in accounting for some accidents in complex systems (Hollnagel, Woods, & Leveson, 2006).

3.2.2 A Shift in Perspectives on Safety

Upon consulting some of the contemporary literature surrounding safety, one notes there has been what one may consider as a change in the way safety is more recently typically being conceptualised. Rochlin (1999) provides one early account of an increasingly popular assertion; that safety is fundamentally something more than just the reflection upon and reduction of threats and their resulting adverse outcomes:

> "...What was found instead was an operational state that represented more than avoidance of risk or management of error. Those organizations

> characterized as HROs [High Reliability Organisations] all show a positive engagement with the construction of operational safety that extends beyond controlling or mitigating untoward or unexpected events and seeks instead to anticipate and plan for them."

Rochlin proceeds to describe how "anticipation" and "expectation of future surprise" are qualities which are observed in highly reliable organisations and play a valuable role in contributing to safety, in addition to the reflective and reactionary approach largely adopted by traditional safety work. Of course, it would be incorrect to assert that prior to this account, there was no proactive dimension to the safety literature, but a renewed emphasis on expanding this active or positive aspect of safety has in recent years become a feature of the literature, and constitutes a movement toward the resilience perspective as previously discussed.

As was alluded to in the opening of the current section, much of this perspective shift is associated with the notion that traditionally, safety is primarily considered in terms of its absence, as opposed to its presence. Reason (2008) refers to this observation as *The Two Faces of Safety* and separates what he refers to as 'negative safety' (reactive attention directed towards accidents, incidents, adverse events, harm and near misses) from what he terms 'positive safety' (which "...relates to the system's intrinsic resistance to its operational hazards").

This is a sentiment somewhat echoed by Eric Hollnagel, who has more recently drawn an explicit distinction between two systems or approaches to considering safety, which he terms *Safety-I* and *Safety-II* (Hollnagel, 2012). This notion is largely compatible with the distinction that Reason (2008) proposes whereby the former, Safety-I, is taken to describe the largely traditional account of safety (focusing on "where things go wrong" and responding in a largely reactive manner). Safety-II however, refers to the practice of "Ensuring things go right", and is deemed to be primarily *pro*active, as opposed to Safety-I. One crucial implication of this distinction which Hollnagel is keen to emphasise, is that the routine, everyday successful operation of systems can be as legitimate and valid a target for empirical

investigation as the adverse events, incidents and near misses upon which traditional safety work largely focuses. Indeed, Hollnagel goes on to suggest how, given the frequency of adverse or remarkable events is relatively extremely low compared to occurrences of routine safe system functioning, and given how these have largely been neglected as a source for learning in the past, there may potentially be more to learn from non-failure events than there is to learn from failure events.

It is worthy of note that the notion of Safety-II links directly with the previously discussed RE literature, and the arguments made by Holnagel regarding the investigation of normal practice have been made both in discussions on Safety-II as above as well as in discussions regarding RE (Hollnagel, 2011):

> "The focus for safety efforts is usually, and traditionally, the unwanted outcomes, injuries, and losses that are the result of adverse events... Resilience engineering, however, defines safety as the ability to succeed under varying conditions. It is a consequence of this definition that it is equally important to study things that go right as things that go wrong.... And it is both easier and more effective to increase safety by improving the number of things that go right, than by reducing the number of things that go wrong."

Much of the work described throughout this thesis leans upon this notion of studying what "goes right" in addition to what "goes wrong", and assumes there is likely to be considerable value in the former, as well as the latter. It should be noted that while some are keen proponents of studying routine and 'safe' practice, the obvious and tangible value of learning from incidents and adverse events is not to be negated. The emerging resilience engineering perspective acknowledges the value of both approaches and considers "proactive/Safety-II" investigation as being complementary and not contradictory to the more established, reactive/Safety-I perspective.

3.3 The Study of Human Performance

In work previously described, the concept of safety is predominantly conceptualised as a property of a system, and thus it is considered in high-level terms and in a manner in which human performance represents only one layer or component among many. Given the phenomenon of resilience strategies is inherently human and largely behavioural, and also considering the context of the current PhD adopting a HCI-centric approach, it also becomes appropriate to consider the intricacies and complexities of human performance which forms another framing or contextual aspect of the existing literature, while not directly comprising the study of resilience strategies proper.

It should be noted at this point that a number of approaches and techniques exist for the analysis of how humans operate, and how work and the completion of tasks are achieved. The study of how work is done encompasses an expansive body of literature which, given the relatively ad-hoc and inconsistent emergence of resilience strategies when considered outside of specific tasks and settings, extends far beyond the scope of the current topic, and thus the summary presentation of related literature here is necessarily not a comprehensive or expansive account of this work. The literature in this chapter instead represents a selection of publications addressing concepts that were deemed most relevant to the topic of resilience strategies, based upon perceived applicability to the topic of resilience strategies, and retrospectively based on the findings from our own work described later in the thesis.

3.3.1 Human Error

With human performance comes the potential for human error. Many work domains (including the area of healthcare, the area forming the backdrop of the current thesis) often involve performing multiple, complex tasks situated in challenging or unpredictable environments- circumstances in which error will inevitably arise in some cases. While we must accept that humans are not ‘perfect machines’ and the nature of human performance carries inherent variability (as

explored in the literature following), investigating error and its causes and reducing the likelihood of error is one immediate course of action which can be taken to improve safety, and indeed much effort has been invested in pursuit of this goal.

With regards to the topic of the current thesis, error can be seen to represent one key threat to performance which resilience strategies serve to mitigate. James Reason (1990) described how "correct performance and systematic errors are two sides of the same coin", which reflects the dichotomy between error and resilience (which one could describe as analogous with correct performance, as discussed by Hollnagel, Braithwaite and Wears, 2013).

Much of the fundamental work on error concerns the description and classification of a number of different types of error. This work helps inform our understanding of the various ways in which we as humans make errors, and provides a more clearly defined set of issues to address in terms of crafting interventions to reduce the chance or impact of errors. Such work is also valuable in that it provides us with a working vocabulary with which to discuss, compare and contrast the various different errors which may be observed, thus facilitating their targeted investigation.

One early example of such work is provided by Norman (1981) who discusses a type of error referred to as *Slip Errors* in some detail. Much of Norman's discussion extends beyond the current literature account, however in summary Norman conceptualises slip errors in the following way:

> "The three major categories of slips are:
> (a) errors in the formation of the intention (which includes the subcategories of mode and description errors);
> (b) faulty activation of schemas (which includes the subcategories of capture errors, data-driven and associative activations, loss of intention, and misordering of action components); and
> (c) faulty triggering (which includes the subcategories of spoonerisms, blends, intrusions of thoughts, and premature triggering)

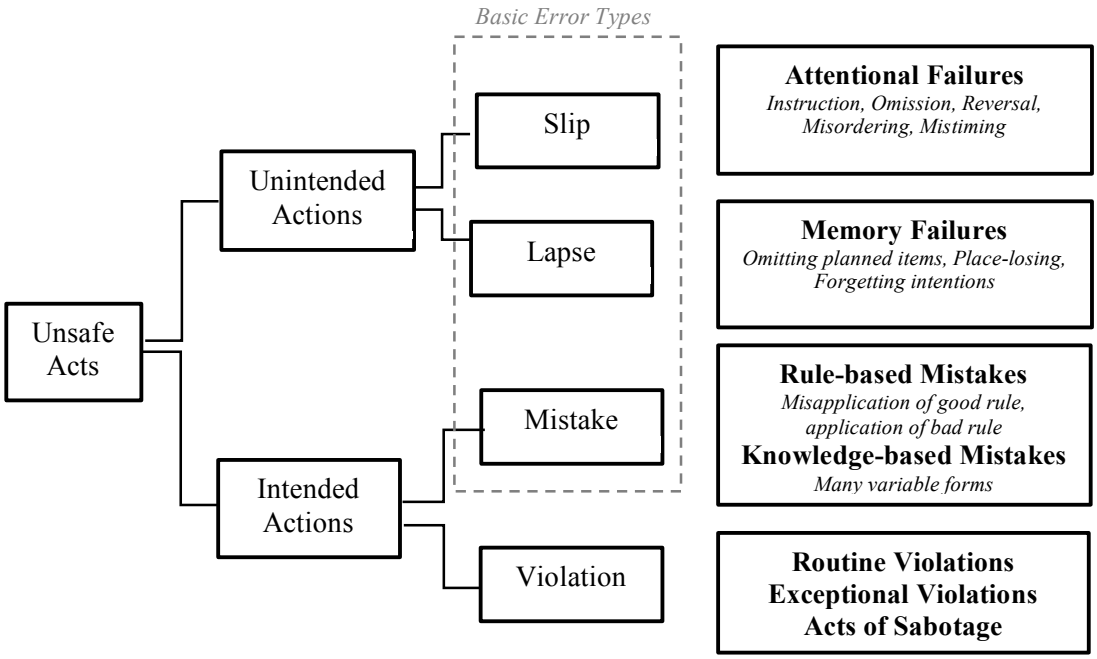


Figure 8. Reason's GEMS (Adapted)

James Reason (1990) in his seminal text, *Human Error*, presents a further classification of different types of error, in terms of four broad subtypes; *slips* (which, unlike in Norman's above description, describes errors which are based on a correct intention but with accidental error at the point of execution), *lapses* (errors in memory leading to the omission of steps), *mistakes* (selecting an incorrect 'plan' by, for example, confusing two items) and *violations* (deliberate and intentional error). Reason also builds upon Rasmussen's SRK framework (1987), further described in 3.3.3 below, which proposes the existence of behaviours at a *Skill, Rule* or *Knowledge* based level. In combining the '4 types of error' classification with Rasmussen's levels of behaviour, Reason develops the *Generic Error Modelling System* or *GEMS*, represented in Figure 8.

While the Generic Error Modelling System, as the name implies, is envisioned as an approach to investigating error independent of domain, GEMS is often conceptualised also as being a taxonomy of sorts, in terms of types of error or

behavioural phenomena (e.g. in Kirwan, 1994; Whittingham, 2004; Ritter, Baxter and Churchill 2014 among many examples). Indeed, it is within this context, serving as a taxonomy, that GEMS is perhaps most relevant with regards to the thesis topic. Its articulation of a number of more specific subtypes of error, represented in the right-most column, provides a more fine-grained account of some of the threats that may be encountered in the study of resilience strategies (some of which we revisit in Chapter 8), while it again serves to demonstrate the utility and value of approaching the study of error by identifying and dividing it into subtypes and categories, an approach we later adopt in our investigation of resilience strategies.

It is important to note at this point however that while the work of both Norman and Reason represents seminal accounts in terms of the classification of errors, by no means do they constitute an exhaustive account of the different types of error that have been identified. Numerous other subtypes of error beyond these feature in the literature, and the vocabulary for errors still varies from one investigation to the other (as noted by Hollnagel, 1998; Fotta, Byrne & Luther, 2014, in their efforts to collate error taxonomies). There are also entire bodies of literature surrounding further niche or highly specific categories of error, the concept of *post-completion errors* (for example, leaving the original document in a photocopier upon completion of the primary goal of generating copies) as explored by Byrne & Bovair (1997) constituting one particularly pertinent example within the context of this thesis.

While a vocabulary for highly specified subtypes of error is emerging, so too efforts are underway to explore errors specific to certain domains, given that the frequency and nature of some types of error will vary significantly based on context and the resulting errors can be highly specialised or embedded within domain-specific scenarios. Wiener and Nagel (1988) for example dedicate a chapter to errors largely specific within the field of aviation, while Taib, McIntosh, Caponecchia, & Baysari (2011) present a literature review into the classification specifically of errors within a healthcare setting. Also within the medical domain, a growing body of investigation is focussed specifically on the types of errors which can arise from the

use of different number entry systems, a target of several other CHI+MED researchers (Thimbleby & Cairns, 2010; Wiseman, Cairns, & Cox, 2011).

While a comprehensive, specifically targeted review of the literature on error might seek to identify, collect and explore the intricacies of the multitude of error subtypes that exist, such an undertaking is considered beyond the scope of the current review. Error, after all, represents but one of a multitude of threats that may be addressed by the use of resilience strategies (with others including environmental factors, frailties in technology, or weaknesses 'higher up the chain' within a sociotechnical system). The wider concept of 'threats to performance' itself also does not fully capture the motivations one may have for utilising a resilience strategy; in many instances, strategies may be motivated by enhancing system performance by, for example, increasing efficiency or promoting optimal practice.

The literature on error does represent a valuable component of the relevant existing work that frames the study of resilience strategies, and some of the concepts introduced here are revisited later in the analyses of our studies and the closing discussion, however as with all of the topics presented in the current literature review, the topic of error represents only part of the picture in our efforts towards better understanding resilience strategies and behaviours.

3.3.2 Memory, Attention and Interruptions

The reasoning for making reference to the literature surrounding memory and attention within this portion of the literature review can be seen as twofold;

(i) Limitations in memory and attention represent a potential threat that may be mitigated by the introduction of resilience strategies

(ii) Memory and attention are both concepts that are relevant in the investigation of strategies themselves, and may serve to inform our understanding of how and why certain strategies work

While the topics of memory and attention each sustain a considerable body of literature within the field of psychology, in the HCI space it is not unusual to see discussions on memory and attention 'group' the two concepts. Owing to the high degree of conceptual overlap across the terms, it becomes useful to consider each closely within the context of the other. This is an approach adopted by Donald Norman in his 1969 book *Memory and Attention*, and like Norman, we do not attempt to provide a comprehensive account of the topics, rather we necessarily (owing to the vast amount of work exploring each) select concepts and examples of work comprising a most appropriate fit within the context of our own studies. The concepts presented here have been identified as being of particular relevance to the study of resilience by either being referred to in the RE or closely associated literatures, or having been encountered during the course of the work described later in the thesis.

As in the other literature summaries contained within the chapter, this closely scoped approach inevitably has required a certain amount of subjective judgement in terms of selecting or excluding work, and there will remain parallels between resilience and memory or attention that remain unexplored. To comprehensively explore all of these in depth would be an undertaking that extends beyond the focus of the current investigation, owing again to the fact that the concepts of memory and attention form only a smaller part of the broad theory base and body of existing work that surrounds resilience strategies and behaviours.

A number of foundational accounts and models for the detailed analysis of memory-related and attentional processes exist, including Deutsch and Deutsch (1963), Norman (1968) and Kahneman (1973). While such models provide us with a working understanding of how stimuli may be attended and memorised, much of this work extends beyond the scope of resilience strategies, however fundamentally it does serve to demonstrate that our capacity for both can be hampered by limitations surrounding the nature of stimuli, cognitive ability and environmental conditions and circumstances (the latter of these arguably being the most pertinent in the current context). Kahneman's *Capacity Model* in particular represents useful contextual

material in determining that our capacity to conduct tasks simultaneously is limited by our finite capacity to attend to competing stimuli. This is a notion that has spawned bodies of work into *multitasking* and the disruptive effects of *interruption*, concepts which represent manifestations of some of the types of threat that may be mitigated with resilience strategies.

Gillie and Broadbent (1989) detail a number of experiments with an aim to explore the disruptive nature of interruptions, evaluating the effects of memory load, duration of interruption and the nature of an interruption (or similarity with the primary task). Of these features, the authors determine that the complexity of introducing tasks that are similar in nature to the continuing task leads to the highest degree of disruption, a finding we were able to extract and implement in determining the nature of distractor tasks used in the studies described here in Chapters 4 and 8.

Similarly in this sphere of work, Altman and Trafton (2002) explore how people juggle and manage simultaneous goals in task performance (albeit during the completion of relatively artificial tasks), and moved to consider aspects such as the prioritisation of goals, the effects of interruption and postcompletion error. While their resulting model presents a fine-grained approach to considering goal-based cognition, the in-depth level of granularity employed makes this work difficult to directly translate within the relatively immature field of resilience strategies, given the lack of tools to support detailed analysis of strategies, and often, the grounded and embedded nature of the work in which they are reported. Discussion about the effectiveness of cues was however noted, and forms part of the context that motivated our attempts to explore cue creation as described in Chapter 4.

While a limited examination of relevant work in these fields does indicate the existence of concepts and findings that could serve to support analysis, as well as guide approaches towards the study of resilience strategies, as was discussed in 3.3.1, such work constitutes a gross examination of only a limited subset of the types of threats and challenges that may evoke resilience strategy responses. Work into multitasking and interruptions could clearly form appropriate and useful context for the limited number of strategies that specifically address such threats, however the

scope of our current thesis is broader in nature, in primarily investigating the breadth, variety and intricacies of all manner of resilience strategies. By helping to establish a more robust foundation, both in terms of our understanding of resilience strategies as well as the means to investigate and analyse them, we anticipate that the work contained in this thesis will move us towards a position where the insights from work into memory, attention and interruptions is more directly translatable and applicable within future investigations into resilience strategies.

3.3.3 Human Performance Analysis and Modelling

Insights into cognitive processes such as memory and attention have enabled investigators to move towards building a richer theoretical base considering how people process the world around them, complete tasks and conduct work. As with the introduction of the topics prior, it is worth considering the study of how work is done encompasses an expansive body of literature which, given the relatively ad-hoc and inconsistent emergence of resilience strategies in the grander scheme of things, largely extends beyond our current scope for investigating the current topic. There is however still some merit in considering the opportunities such approaches may afford investigators working within the area of resilience, even if, as later discussed, the current suitability of said approaches within the context of work into resilience strategies could potentially be seen as limited.

Wickens (1992) for example proposes a model of Human Information Processing in his 1992 text *Engineering Psychology and Human Performance* that describes and integrates a number of components and processes involved in information processing, relating aspects of perception, attention and memory into a series of discrete stages, presented sequentially. Such a model could potentially provide structure to inform the in-depth analysis of resilience strategies, however in many cases and when considering the format of typical reported instances of resilience strategies (e.g. those described by Furniss, Back and Blandford 2012, or

the types of anecdotal accounts as discussed later in 3.4.1 and 3.4.2), the richness of available data and indeed current foundational understanding of the topic limits the applicability of such detailed analytical apparatus. We do see potential for Wickens' model however to support analysis of more complex resilience strategies as high level (or hypothetical) prototypes, and consider that the approach has the potential to add a richness to analysis not afforded by current tailored approaches into the study of resilience strategies. For many less complex cases however, e.g. the archetypal 'umbrella by the door' (2.3.6) such a level of investigative scrutiny, at least on the surface, does not appear justified in terms of the insights likely to be obtainable.

Similarly, Vicente (1999) offers a framework to analyse work in complex sociotechnical systems in the form of Cognitive Work Analysis, which provides a means by which to consider the constraints and properties of the work domain and resources contained within. In terms of the notion of applying this work to the study of resilience strategies, we consider there to remain comparable challenges to those outlined prior concerning Wickens' model. The application of the more fine-grained approach of CWA is, to date, rendered challenging owing to the relative immaturity of work specifically into resilience strategies, both in terms of foundational knowledge and the format of strategies we are currently tasked with analysing (owing, at least partially, to a lack of developed approaches thus far to gather and analyse strategy accounts).

In order to best harness such approaches, a more robust foundation of knowledge concerning resilience strategies is required to bridge the gap between these established detailed analytical frameworks and the still emerging field of work into resilience strategies. Enhancing this foundation of knowledge represents the primary aim of the current thesis. While we note these approaches have yet to be leveraged within the (albeit limited) pool of work explicitly targeting resilience strategies, as discussed in 7.6., we see potential for applicability in future when the state of investigations into resilience strategies is more mature, and particularly in situations where narrower and deeper insights into resilience in specific domains or settings is conducted.

3.4 Resilience by Other Names

As described in the previous chapter, resilience strategies can be considered as manifestations of resilience at an observable, individual level, making such strategies a useful target for investigations when approaching resilience from a HCI perspective. As also noted however, there is currently relatively little existing work within the RE literature that specifically addresses these types of strategies.

Consulting the broader literature beyond the realm of RE however, one notes that a number of topics exist in related areas such as psychology, HCI and human factors, which display clear parallels with some types of resilience strategies. In this portion of the literature review, we introduce a selection of these concepts, identified primarily by tracing back concepts identified from Furniss, Back and Blandford's (2012) categorisation scheme for resilience strategies, and summarise some of what we deem to be the more relevant work that has been conducted within these topics. While we would consider this work as highly relevant, much makes use of a different vocabulary and indeed carries a different emphasis, and so discussion here is limited to relevant implications for individual or cognitive resilience which we can take from such work.

3.4.1 User Adaptation & Workarounds

The topics of workarounds and user adaptations on the front line have received some attention in the literature, and are obviously of interest when one comes to consider how individuals demonstrate resilience. In some cases, there appears a fine line between a resilience strategy and a workaround, and the terms might even be used interchangeably to label certain behaviours. However, in considering the context of existing work in the areas of adaptation and workarounds, one notes a significant difference in terms of attitudes towards such phenomenon.

The literature addressing workarounds reveals that traditionally, much emphasis has been placed on exploring the risks and challenges associated with individuals' adaptations and workarounds. The general perspective of many

researchers in the field, one might argue, largely neglects the potential possibilities of harnessing the positive attributes or outcomes that may be attached to workarounds. Instead, it is all too easy to find evidence of workarounds being presented as a threat or a problem, something which should actively be guarded against or discouraged. The language used in a recent widely circulated whitepaper conducted by HIMSS media and sponsored by Intel (HiMMS/Intel, 2013) illustrates this clearly: within the report, titled *Workarounds in Healthcare, a Risky Trend*, lies a section explicitly addressing 'Curbing Workaround Usage'. While this specific whitepaper primarily addresses workarounds in terms of the mishandling of data in the BYOD ('Bring Your Own Device') era and so targets the privacy and security of information rather than frontline patient care, its characterisation of the practice of workarounds as being detrimental to the greater good of the system is a reoccurring theme within the literature, particularly within the healthcare domain.

In a relatively highly cited paper investigating workarounds within the field of healthcare, Koppel, Wetterneck, Telles, and Karsh (2008) describe workarounds in the context of Barcode Medication Administration Systems, and follow a similar perspective to that described above. The authors marry the concept explicitly to "violations" as described by Reason, Manstead, Stradling, Baxter and Campbell (1990), and in so doing, inextricably link workarounds with errors. Koppel et al. go on to describe common workarounds within BCMA systems and identify one or more potential errors corresponding with each of the forms of workaround they identify. At the same time however, the authors describe how workarounds are "typically used because of deficiencies in system or workflow design" implying how users of workarounds are demonstrating adaptability (and arguably resilience) to cope with adverse circumstances, however do not go on to explore this dimension, instead favouring approaches to discourage the use of workarounds.

This inevitably reintroduces a question posed earlier (2.3.8) concerning the extent to which resilience is a positive contributor to the safety or performance of a system versus potentially being a negative factor. One example in the literature which presents us with an interesting case to consider in terms of user adaptation on

the front line is summarised by Randell & Johnson (2002). The authors describe how they observed nurses in a hospital ward 'tricking' portable monitors by removing and reinserting their batteries. This was done to overcome a 'designed-in' safety feature whereby irrespective of the functional working state of the battery, after every 50 instances of use, a battery condition error would require replacement of batteries (despite them still having some usable capacity). This feature had been introduced to account for the depletion of batteries based on the limited recharging cycles they are able to undergo and enforced a safety margin to ensure batteries were replaced before they became unusable. However in practical, real-world use, the error would sometimes arise during cases where the portable monitor was required immediately (e.g. while patients were in transit), thus staff adopted the workaround of removing and then reinserting the current battery to 'fool' the device into thinking the battery had been replaced. At one level, this is an example of staff demonstrating resilience to complete their immediate goal and overcome the disturbance. At a higher level however, of course this strategy could be detrimental to the resilience of the wider system since it has eroded a designed-in safety margin- i.e. if the staff should forget to actually replace the battery, it might fail later on in use.

Although Randell and Johnson do not make explicit reference to resilience in their discussion of the above practice, this strategy could clearly be labelled as resilient, and rather intriguingly serves to show how a resilience strategy can again simultaneously contribute both positively and negatively to safe and efficient functioning of the wider system. This is a point which Hollnagel et al. (2006) also make reference to in their discussions concerning resilience:

> "…resilience [is] affected by how adaptations by local actors in the form of workarounds or innovative tactics reverberate and influence more strategic goals and interactions (e.g., workload bottlenecks at the operational scale can lead to practitioner workarounds that make management's attempts to command compliance with broad standards unworkable."

While these types of resilient interventions at an operator level can be seen in some cases to introduce frailties higher up in the system, that is not to say they are entirely negative. While in such examples there may be potential adverse implications at a higher level of granularity, there could still be some merit in exploring the positive qualities afforded by such interventions. Returning to Randell and Johnson's aforementioned example, as long as the need to replace the battery is identified and noted, this workaround may introduce a net benefit in terms of safety- if a resource (and at that, an important healthcare related one) is made available at the time it is most needed. This potential for positive outcomes is largely absent from the prevailing discussion on workarounds in healthcare. Furthermore, in many cases, and as we will illustrate with the instances of resilience described later in the thesis, this 'trade-off' between resilience and safety does not exist, leading to 'positive workarounds', which represents what we consider to be resilience strategies.

It is at this point also worth recognising that workarounds, like resilience strategies, can take many forms and the label itself could be viewed as an umbrella term. Another example of the sorts of practices which one might observe and label as either workarounds or resilient strategies (or indeed both) is appropriation.

3.4.2 Appropriation

Appropriation is a term that again overlaps considerably with resilience and with adaptation or workarounds, however depending on one's perspective, might be considered either as a subset or indeed a superset of resilience. As is typical with the intertwined topics being discussed in this section, appropriation refers to a subtly different concept however many examples of adaptation or resilience could also be considered as appropriation and vice versa.

Appropriation refers to the practice of improvising and adapting available resources in ways not originally anticipated or intended, in order to improve performance or minimise error. Alan Dix (2007), talking of appropriation, states:

"…people do not 'play to the rules': they adapt and adopt the technology around them in ways the designers never envisaged…"

This succinctly summarises the essence of the term. Dix goes onto describe several typical examples of where objects or resources may be appropriated, such as using a screwdriver to open a paint tin, or a heavy book to hold a door open.

With regards to HCI, instances of user appropriation when encountering a novel system are frequently observed. Indeed, the notion of appropriation can be seen as an important step in 'finishing the design' and accepting new technologies (Dix, 2007). Dix goes on to present some useful insight into how appropriation can be facilitated at the design stage, in describing a set of broad guidelines. For example, one such guideline is "*allowing* [user] *interpretation*", with the real-world example used to illustrate this being the ability to assign colours to folders in the *Apple OSX* operating system. This is selected owing to the fact it constitutes functionality without explicit purpose, for the user to adapt and appropriate for their own means. In this way, Dix proposes an interesting notion; that the unpredictable and unanticipated actions of the user can still be influenced and accommodated for in the designs of systems. We would posit that this notion, which is central to the aims of the work being presented here, can potentially be expanded beyond appropriation to include the entire range of individual resilience strategies and behaviours.

Another relevant contribution in this area, as previously discussed in 2.4, is offered by Buchanan et al. (2011). This work is amongst the first to explicitly marry and situate the topics of appropriation and cognitive resilience, in describing how appropriation can be used to increase and enhance resilience. The authors make this case by presenting two vignettes; the administration of medication through infusions in a healthcare setting, and an attentive reading scenario in disruptive conditions (using public transport). In each case, an external resource is appropriated to assist performance, by minimising the risk from disruptive threats to attention and supporting progress tracking. Buchanan et al.'s contribution may only take the form of a brief position paper, however crucially it establishes this link between resilience

and appropriation and in doing so, articulates what is seemingly one of the cornerstone concepts involved in a large proportion of instances of individual resilience.

As what might be considered as a scoping exercise however, it is worth noting at this point that not all examples of appropriation necessarily constitute resilience and there does exist a meaningful separation between the two concepts in some cases. One example of appropriation arguably removed from resilience would be the Dix's aforementioned example of using a heavy book to prop open a door. Similarly, such an example also distances appropriation from the previously discussed topic of workarounds.

Appropriation can however further be tied to another of the topics discussed in this section; the use of cues. In the previously aforementioned example of an individual resilient strategy involving the umbrella as a cue by the door, the umbrella as an object could be said to have been appropriated as the user has assigned it to serve a purpose for which it was not originally designed, as part of their resilience strategy to minimise the chance of it being forgotten. This relation between cueing and appropriation in particular becomes a recurrent theme during the course of later work, and as such is explored in greater depth in Chapter 7**.** The topic of cueing and its relevance to individual resilience is explored below.

3.4.3 Cue Creation and Strategies to Support Working Memory

The creation and use of cues to pre-empt and avoid prospective memory slips is a relatively established phenomenon in some of the psychology literature. At the same time, in the case of many common individual resilience strategies, cueing is a reoccurring theme and indeed, one of our own oft-cited prototypical examples of an individual resilience strategy (the 'umbrella by the door example' discussed previously) is primarily a cueing strategy.

Cues are typically stimuli in the environment that are employed primarily to assist prospective memory (although also have a related role in directing attention).

Cues can take multiple forms, however are most frequently visual or auditory. Indeed, visual cues can themselves be represented in a multitude of ways, and can range from on-screen artefacts to repurposed or appropriated physical objects. There are also aspects of cueing that prove more tacit, for example in task/workload management where a sequence of actions may be restructured in order for one subtask to cue another.

There is an extensive body of work looking into all aspects of cues, again much of which is not directly relevant here. However, some work has specifically investigated how individuals utilise cues to improve performance, and where existing work discusses the factors which contribute to the effectiveness or otherwise of a cue, there seems some potentially valuable insight to be drawn. One such example of potentially useful work within the topic is presented by Chung & Byrne, 2004 and summarised by Byrne, 2008. Drawing on a sequence of controlled experiment studies, the authors conclude that three critical factors above all else influence the effectiveness of a cue. Moreover, the authors illustrate these principles with examples from past work (Byrne, 2008):

- *Salience*: The display used was a grayscale display, so the blinking coloured arrows had a high level of perceptual salience.
- *Specificity*: Unlike the beeping of the ATM, which is non-specific, the cue used made it clear to the user exactly what to do: the arrows pointed directly to the relevant button on the display.
- *Just-in-time*: The cue appeared right at the moment that action on the critical button needed to be taken. Thus, it did not rely on the user to have to remember to take action at a specific time.

With regards to the relevance of cuing to individual resilience strategies, it would seem that strategies involving some aspect of cueing appear by far the most commonly reported (Furniss, Back and Blandford 2012). One could argue it is however not entirely clear as to whether this observed frequency is a genuine

reflection of their being the most commonly utilised or whether they are simply perhaps the most tangible and thus reliably reported. Also worth recognising when situating cues within the topic of resilience; the mere act of utilising a cue in the environment to assist with memory is not in and of itself an example of resilience. Where individuals partake in the creation or configuration of a cue however, one most likely is observing individual resilience.

Owing to the prevalence of resilience strategies featuring cues, the topic of cueing is of particular interest here. As such, an initial study conducted as part of this work looked specifically at how individuals might configure cues in a lab study paradigm, and whether such cues would lead to any performance effect. This work is outlined later in Chapter 4, together with an expanded account of the relevance of cues within the topic of resilience strategies.

3.4.4 Task or Workload Structuring

One of the things to come out of the initial study (as outlined in the following chapter) was that individuals frequently adjust or optimise the process or steps in a sequence they are undertaking to improve performance. The extent to which this is reflected upon 'in action' (making reference to Back et al.'s aforementioned distinction between on action and in action) and ultimately whether this constitutes individual resilience in terms of strategy formation and use is debatable and at the very least, varies from case to case. As a potential class of resilience strategy, the idea of 'task-structuring' again provokes reflection on whether actions which are not consciously being reflected upon can be considered as resilience. However, it's difficult to ignore that this again forms one way in which users may take action to mitigate perceived risks or optimise performance, and in some cases this is executed with conscious forethought.

Building on the topic of 'cues' as discussed in the previous section, it is worth beginning by saying there is again some overlap here between these different topics. One of the common ways in which performance improvements are gained by

restructuring the order of tasks is through using one action to cue the next. In some cases, this may be forced upon the user (for example, the often cited HCI example of the sequence of operations performed by an ATM) however in other cases, users themselves may modify a sequence so as to increase the salience of the next step. This is essentially what was observed in the initial study as described later. Subjects tasked with completing a form which placed demands on their working memory deviated from the instructed sequence of data entry in order to minimise the risk of error by leaving values in fields, providing implicit visual cues to track progress and resume from interruptions more accurately.

Furthermore, subjects also altered the structure of the task by carefully managing the way they alternated between a primary and secondary task, deferring interruptions at a macro level to ensure their primary tasks were paused in a logical place- that is to say, between subtask boundaries, as predicted by the work of Iqbal & Bailey (2006). Further and more detailed discussions surrounding these behaviours, observed first hand during the initial study, are presented in 4.5.

3.4.5 Verbal Rehearsal to Assist Memory

Another observation noted from the initial probing study (described in the following chapter) was the tendency for people to use verbal rehearsal as a means to assist information retention and facilitate working memory. To date, we have not found evidence of this concept being discussed in the context of resilience strategies, however the use of rehearsal in work on memory is established (Norman, 1969) and specifically verbal rehearsal as a memory strategy has been widely explored and discussed within the psychology literature.

The term ‘verbal rehearsal’ essentially describes a strategy or behaviour whereby an individual repetitively verbalises information they wish to retain. The concept has been applied across a variety of contexts in the psychology literature, particularly surrounding memory development in early childhood (Flavell, Beach and Chinsky, 1966), language acquisition (Baddeley, Gathercole and Papagno,

1998), and learning difficulties or neurological disorders (e.g. Rothi and Hutchinson, 1981). Its application more generally within the area of working memory is the subject of much work, as recently sumarised by Lucidi et al. (2015) who describe its importance in retention in short term memory.

Strategies involving the verbal rehearsal of information could be said to be a manifestation of the *phonological loop*, a fundamental component of one of the prevalent models of working memory in modern psychology, presented by Baddeley and Hitch (1974). As remarked by Baddeley et al., the loop "comprises both a phonological store, which holds information in phonological form, and a rehearsal process, which serves to maintain decaying representations in the phonological store".

Our observation of participants repetitively uttering items of information during interruptions as part of our initial probing study provoked reflection on the extent to which behaviours that individuals deploy, sometimes subconsciously (as some participants were seemingly unaware of their verbal rehearsal) constitute resilience strategies, a topic further discussed in the following chapters.

3.5 A Working Definition of Resilience Strategies

Given the relative immaturity of targeted and specific work into resilience strategies, as well as the variety of existing definitions of resilience (presented in 2.2) and a number of ambiguities (identified and discussed in 2.3), it is necessary to present a working definition of a resilience strategy, in order to convey our position on the phenomenon and provide scope and clarity to the work contained herein.

We therefore conceptualise resilience strategies as follows:

Observable behavioural interventions that individuals utilise to pre-empt, adapt to or recover from threats or disturbances, in order to maintain or enhance performance and minimise error or risk.

Here, we deconstruct this definition into what we consider to be its significant components, with reference to concepts and other definitions identified from the literature as discussed in Chapters 2 and 3.

Our first position on resilience strategies is that in order for them to be effectively investigated, we consider they must be observable, or result in observable output or an observable course of action. In the formulation of our definition, we term these observable (or with observable consequence) actions, taken by the individual/user as 'behavioural interventions' which corresponds to the term 'strategy' component of resilience strategies.

This introduces the notion of 'intentionality' as discussed in 2.3.7., owing to the term 'strategy' implying a planned intent. For the purposes of the work here however, we adopt the position of broadening our scope to consider tacit or repeated/subconscious behaviours, encompassing both 'Big R' and 'little r' resilience (Furniss et al., 2010, discussed in 2.3.4)., as well as including implicit or tacit actions such as task/workload structuring or verbal rehearsal (discussed in 3.4.4 and 3.4.5 respectively). We adopt this stance with a view to being comprehensive, considering these concepts to be strongly functionally overlapping and analogous, and in taking an inclusive position, we maximise the space of phenomena to explore as strategies, rather than narrowing this to only the more explicit or overt cases.

The use of the term 'individuals' is a deliberate choice, one which contrasts with the option of 'users' perhaps more conventionally applied in HCI. As demonstrated by Furniss et al. (2012), resilience strategies can be studied beyond the confines of interactions with technology, and approaching the topic with this broadened scope could lead to a broader variety of potentially transferable cases. The term 'individuals' also delineates that we are approaching the topic with a focus on individuals, as opposed to at a sociotechnical level of granularity more commonly adopted within the sphere of work into resilience engineering.

Using the terms 'pre-empt, adapt to and recover from' represents a direct reference to the definition of resilience offered by Boin et al. (2010), discussed in

2.2. This phrasing reflects our position that we consider resilience may occur both pre-emptively and reactively (a notion discussed by Hildebrandt et al., 2008, presented in 2.3.3, and also recognised in Hollnagel et al.'s 2013 definition).

Concerning 'threats' and 'disturbances', this again adopts language used by Hollnagel et al (2013), discussed in 2.2. We do not make reference to the scale of a threat or disturbance, as discussed in 2.3.6, leaving our scope open to include both major threats or everyday strategies addressing more minor challenges.

The term 'maintain' in a performance context is borrowed from an earlier definition by Hollnagel et al. (2006), and combined with 'enhance', which reflects Hollnagel et al's (2010) later discussion concerning the option for resilience to capitalise on 'opportunities' as well as coping with threats and disturbances.

Finally, the terms 'error and risk' are used as an indicator of some manifestations of threats, as well as affirming our position that resilience strategies contribute positively to safety.

As discussed, it is worth reiterating that the definition we form here represents something of a working definition, and encompasses our position on a number of aspects upon which there appears no available consensus. We do not forward the above as an unequivocal or even entirely objective definition, rather a marker to contextualise and scope the work described later. We revisit this definition later in 9.3 in the context of discussing our research questions.

Chapter 4: Study I: A Probing Study to Investigate User Configured Cueing and Further Resilience Strategies in an Interrupted Task

4.1 Chapter Introduction

This chapter introduces and describes the first study that was conducted as part of this PhD. The chapter provides a discussion of the background, rationale and aims behind the study, making reference to the previous chapters describing the current literature and how this work helps to address the broader aims of the PhD. We then move onto the practical details of the work, describing the setup and conduct of the study, before closing with a discussion summarising our observations and findings, an evaluation of the study and what it raised, and subsequent implications of this work.

During the conduct of the 'controlled' task central to the study, we soon observed a range of unanticipated resilience-related phenomena that, while undermining the initial objective of the work, presented clear opportunities to examine a broader range of resilience strategies and behaviours. This resulted in us shifting the focus of this work mid-study, adapting our approach accordingly to accommodate for this unforeseen but ultimately pivotal and insightful new direction.

Consequently, to remain faithful to the work as it was undertaken, we open our account of the study by discussing how it was initially conceived as a controlled study, however we later go on to report and discuss a number of findings and insights that extended beyond the confines of the controlled paradigm we attempted to establish. The resulting study, despite its design and inception, should ultimately therefore *not* be considered as a formal controlled study, but rather an exploratory, probing study leveraging a 'controlled laboratory study like' format.

4.2 Study Introduction and Rationale

As described previously, the broad aims of this thesis are to better understand how users of technologies perform resilient interventions to manage and maintain performance. Based on this research direction, as well as a perceived gap in current understanding with regards to users actively engaging in cueing behaviour, we designed a 'probing' study to explore a specific subset of resilience strategies or behaviours. This initial exploratory study also provided a first-hand opportunity to gain experience in determining how resilience-type behaviours might be instigated and investigated within a controlled study paradigm.

Due to the inherently extensive nature of potential resilient strategies, it was decided that we would initially limit the scope of our investigations to only consider a subset of resilience strategies. This was intended to deliver a clearer and more concrete focus, and it was presumed that by breaking down the expansive phenomenon of resilience strategies into more manageable units of analysis, and studying one of these in relative isolation, we would make the topic more easily digestible. In determining this area of focus, we opted to refer back to the literature in an attempt to build upon the limited existing work addressing the topic.

As covered in the literature review, current understanding in terms of the resilient strategies users deploy to address perceived threats or maintain performance is somewhat limited. However one of the more graspable and clearly defined examples of resilient strategy usage involves the utilisation of cues to support working or prospective memory, as illustrated by Furniss, Back and Blandford (2011) and discussed previously in section 2.4. As noted, there is a body of literature specifically addressing cues, and cues have been shown to be effective in assisting users with maintaining performance and managing threats, particularly within the context of placekeeping or progress-tracking during interrupted tasks.

Work conducted elsewhere within the CHI+MED project has described how interruptions can be a pertinent issue in safety critical work such as healthcare (Rajkomar & Blandford, 2012) and one in which interventions specifically in HCI

have the potential to reap rewards (Brumby, Cox, Back & Gould, 2013). In some cases, these cues can be implemented into a system or interface by designers and 'hard-coded' into the interaction paradigm. However, it is not always possible to anticipate and provision for the cueing support any user might need in a given situation, owing to a host of complications and variables that extend beyond the designers' sphere of influence (such as unpredictability in the environment and the frequency, timing and nature of interruptions, the potential for unanticipated complexities in real-world tasks, user familiarity and competency etc.).

In these inevitable situations where hard-coded cueing support is not available or sufficient for the user, some previous work has demonstrated that users may actively devise or appropriate their own cues. As previously described in 2.4, Back et al. (2008) observed one concrete example of this in the way users directed their placement of the mouse cursor during an interrupted task, appropriating this persistent user interface element as a rudimentary cue to direct attention upon task resumption. While the study presents interesting insights into how users develop and utilise such tactics, and suggests that these measures can enhance performance and reduce the threat of errors, the observation of this strategy was identified during a post-hoc performance analysis. To date, the targeted direction of investigations into this specific phenomenon, and in particular to how these user-developed or improvised cues compare to cues already present in an interaction paradigm, appears lacking within the literature.

Based on this, we devised an initial study which sought to investigate in a controlled setting whether users might engage with the potential to configure their own cues, and whether this would result in any improvement in performance during a complex, challenging and interrupted task. While the current thesis is not scoped to focus specifically on healthcare, it is noted that the medical domain represents the type of area where improvements to our understanding of resilience could introduce benefits in HCI, and that this PhD has been conducted and funded as part of a project looking into the HCI of medical devices. We thus opted to leverage a medical scenario in our selection of a generic task to investigate cue creation, with this

healthcare context in mind. The task, as later described, was designed to loosely simulate a common HCI-related task performed by healthcare professionals, the administering of medication using digital 'infusion pumps' while remaining sufficiently artificial so as to enable recruitment of a general (i.e. not healthcare trained) sample of participants, and to not necessitate extensive ethical oversight, as would be required in a genuine clinical context.

4.3 Study Aims

Building on previous work as described, the current investigation sought to explore the phenomenon of user created or configured cues, and in particular the implications of such cueing in terms of performance and the reduction of error. As an initial, exploratory and probing study, the investigation also sought to inform us not only about the phenomenon of resilience, but also about the practical and methodological issues surrounding its targeted investigation.

We can summarise the intended contributions of the investigation in the following, more concrete and specific aims:

1. To design and implement an instrument and study design which would afford us the ability to elicit and examine cues and other resilience strategies

Although less of a primary aim of the investigation and more of a precursor required to achieve subsequent aims, it is worth emphasising that given a limited base of pre-existing work addressing this topic, the success of this study hinged on our ability to construct a study paradigm that would elicit user-configured cues and other resilient strategies and enable their analysis. Given the 'probing study' nature of this work, the design of the task and apparatus was recognised in itself as a potential source for practical lessons on how to conduct future work in this space.

2. To determine whether users would actively engage with the process of configuring cues as a means of improving their resilience in response to challenging conditions

With the notable exception of the aforementioned work presented by Back et al. (2008), and to a lesser extent Furniss, Back and Blandford (2012) (whose observed cueing strategies predominantly existed outside of HCI and interactions with technology), there is relatively little explicit reference in the HCI literature of users developing resilience strategies. A subsequent objective of this work was thus to validate the notion that users do deploy resilience strategies in the specific context of HCI and the operation of interactive technologies.

3. To investigate potential effects on performance that may be associated with the use of resilience strategies

The initial work by Back et al. indicated that the utilisation of resilience strategies may lead to improvements in performance, however as noted, observations of strategy use were derived from post-hoc analyses from a study that principally had a different target for investigation. By generating a purpose-built, controlled setup with an explicit focus on resilience strategies, we aimed to explore performance effects more closely by drawing comparisons between not only the absence of cues, but also against a system which presented cues hard-coded into the interface.

4. To observe and record any additional strategies users deployed, and afford users the flexibility to compose or configure their own cues

While this study attempted to control for extraneous performance effects of other strategies by reducing the space of available alternative strategies (to facilitate the intended focus on cueing behaviours), we conceded that there would be the potential for users to develop ingenious and unanticipated strategies. An additional and secondary aim of this study was therefore to recognise and record any such instances, both to deliver insights into additional examples of resilience strategies, and again to develop practical or methodological knowledge which may be applied to future investigations in the area.

4.4 Study Design and Methodology

In order to explore the notion of users engaging with the creation or configuration of cues as a means to assist placekeeping, we developed a study paradigm requiring multitasking on the part of our participants, modelled loosely upon a real-world scenario in frontline healthcare. In this exercise, participants performed a primary on-screen task involving calculation and data entry, while being interrupted with a secondary (distractor) paper-based task of a similar but less complex nature. This paradigm was developed with the threat of placekeeping errors specifically in mind, with an expectancy that users may benefit from appropriating onscreen interface elements as ad-hoc cues to facilitate task resumption following interruptions.

The following comprises a more detailed description of our sample, of our rationale in the design of the paradigm, and of the tasks which participants were asked to complete during the course of the study.

4.4.1 Participants

A total of 29 participants of varying age, gender and occupation were recruited as an opportunity sample for this study (a further participant was initially recruited for a total of 30, however was unavailable at the time of the study).

Recruitment was conducted via requests sent to a department email list, as well as a poster placed on several departmental noticeboards, and a brief pitch presented to several taught seminars within the Centre for HCI Design, City, University of London. The study therefore primarily consisted of students and researchers working in the field of HCI.

No prior specialist knowledge or expertise was required by participants, and no exclusion criteria were set (beyond requirements as specified by the school ethics policy regarding vulnerable populations, minors etc.).

To reimburse participants for their time, each participant who completed the study was reimbursed to the sum of £10.

4.4.2 Materials and Apparatus

Participants were provided with a pen and consent form, information sheet as well as an instruction sheet containing full instructions which guided them through a training exercise encompassed both primary and secondary (distractor) tasks. The study was primarily run on-screen, using a Windows PC and standard input peripherals (mouse and keyboard). Paper materials necessary for the running of the study (presented in Appendix A), both in terms of the primary task and also a secondary distractor task, were also provided.

With regards to the specific apparatus upon which the study was conducted, a custom-designed task interface was scripted in Visual Basic using *Microsoft Visual Studio* (again, described below within the context of the instructed task) for the purpose of the study. Participants were also provided with a calculator, in the form of the built-in Windows 7 on-screen calculator, which was left open on the screen for them to use during their completion of the task.

4.4.3 Study Design

As described in the opening of the chapter, the study was originally conceived as a controlled investigation, in the form of a laboratory study. The use of this methodology was motivated by a desire to draw performance comparisons between analogous tasks in a manner not otherwise possible. The decision was also based on the background of the investigator, approaching the topic from a cognitive science perspective, with experience in the design and execution of controlled studies. It should be noted that while the use of artificial tasks in a controlled paradigm is a relatively unestablished method within the context of resilience investigation (the only clear example of which being the aforementioned Back et al. 2008 study), such an approach has been widely applied within the sphere of work on error, specifically post-completion error and interruption (for example, several such investigations have made use of the ‘doughnut machine task’ developed and

described in Li, Blandford, Cairns, & Young, 2005, which formed a loose basis upon which to build the design of this study).

This methodological approach afforded us the opportunity to observe performance effects as well as strategies and behaviours which deviated from the instructed path, and allowed for exploratory analyses of any potential associations between strategies and error rate. It should be noted that we were not attempting at this point to establish cause and effect, but the use of a controlled format was at least intended to reduce a potential wealth of mitigating and influencing performance-affecting factors which may have been present in a less structured setup. This also seemed like a natural way to expand upon the limited work already undertaken in this area which had, as noted, involved post-hoc sense-making of observed instances of resilience as opposed to focussed and directed investigation.

The study was originally designed as an independent samples controlled investigation, with three conditions. In the primary experimental condition, participants were extended the opportunity to generate or configure their own cues. In the control condition, any identified potential cues were 'designed-out' of the interface, with the intention being that no cueing support would be available for participants. A third condition was also present for additional comparisons, in which cues were hardcoded into the interface, to establish performance data representing a system in which cues are designed-in. These three conditions are reflected in three subtly differing on-screen interfaces that were used in the primary task, which is described in more detail and illustrated with screenshots in the following section.

The three conditions thus represented the primary independent variable for the study, with the intended primary dependent variable being the error rate that participants displayed, which was taken as the indicator of performance. A secondary dependent variable of sorts which we looked to record was the potential adoption of any further and unanticipated resilience strategies, and the nature of any such strategies themselves.

Regarding anticipated findings, for the study as designed originally, our original one-tailed hypotheses was that we would observe an association between the

presence of cues (in either a user generated or system-mandated format), and enhanced performance (which would manifest in the reduction of error rate). This hypothesis appeared consistent with previous work investigating the efficacy of cues as a means to provide support for users in challenging scenarios, as previously described in 3.4.3. As we later describe however, we moved away from this hypothesis during the actual conduct of the study, instead ultimately focusing on a broader spread of strategies and behaviours.

While we did not have sufficient basis to inform any predictions regarding performance differences between the 'user configured cues' and 'hardcoded system cues' conditions, we were keen to learn whether any notable differences between these conditions would be observed.

Finally, we also predicted that we would observe some additional cueing strategies on the part of users, potentially involving the use of the physical materials provided (pen and paper). However, we expected only a limited level of such strategy formation, given our efforts to reduce the potential space of cues and other strategies available to our participants.

4.4.4 Task Paradigm and Procedure

In considering this study's setup, one problematic question concerned how to extend participants the freedom and flexibility to create their own cues, while from an experimenter perspective retaining sufficient control to extract data with the consistency for meaningful comparative analysis. Such a paradox, as far as we were aware, had yet to be addressed in the relevant literature.

It was decided that affording participants complete flexibility in the process of generating cues would most likely return inconsistent and disparate examples, not conducive to structured comparisons or analysis. We therefore opted to instead work on the basis that rather than generating cues 'from scratch', participants would instead be implicitly tasked with appropriating a series of onscreen artefacts, which took the form of empty checkboxes, to form their cues.

The task we opted to compose for the study was modelled on a common task within our adopted domain of healthcare: setting up a number of courses of medication to be administered intravenously. This particular task increasingly involves the operation of interactive medical devices (thus has a relevance for HCI), has a potential for placekeeping type errors, and is particularly susceptible to interruption in a frontline medical setting (echoing the domain upon which the CHI+MED project primarily targets, and building upon the aforementioned observations of colleagues on the project (e.g. Rajkomar & Blandford, 2012)).

The task involved performing a number of relatively simple calculations which were of a [*speed = distance / time*] nature, but for medication values: *rate*, *volume* and *duration*. As in healthcare contexts, the label *VTBI* (an abbreviation of *Volume To Be Infused,* conveying the volume or amount of a substance) was used to denote volume. Upon performing these calculations, an element of data entry was then required, which took the form of transcribing data from the paper sheet upon which the calculated values had been recorded into an onscreen form interface (Figure 9). During this task, participants were interrupted a total of four times and momentarily assigned with a paper-based distractor task (verifying a completed set of calculations, shown in Appendix A) before being asked to resume the primary task. The distractor task was intentionally of a similar format to the primary task in order to maximise its disruptive effect as a threat to working memory, which also is reflective of the 'real world' equivalent of the envisioned task.

The primary task comprised of entering three 'cases' (which were intended to represent patients) each requiring the programming of three 'drugs', making for a total of nine 'courses of medication' to enter (each drug requiring four inputs: selection/type of drug, VTBI, rate and duration). The distractor task meanwhile comprised of four cases, each of which featured five drugs, but each case was considerably less challenging to complete than the primary tasks. It should be noted that while performance on the distractor task was monitored to ensure participants were diverting their attention to the task, performance data on the distraction task was not deemed a dependent variable.

Returning to the primary task, the points at which interruptions occurred (i.e. when participants were directed to immediately stop their progress on the primary task and switch to the distractor task) were controlled and predetermined, with interruptions occurring both between and within subtask boundaries, reflecting the fact that interruptions in the real-world can and do happen at any point, and ensuring consistent structure and thus comparable complexity across all participants.

The onscreen form (shown in Figure 9) was arrived at through several iterations of design combined with brief and informal piloting (with three colleagues and fellow PhD students), and implemented in *Visual Basic* as a traditional Windows form interface. The layout was carefully considered and, together with the instructed sequence of data entry, presented two key challenges to completing the task:

1. Place-keeping, owing to the fields auto-clearing upon an entry button being clicked, which eliminated values from fields that would have represented an implicit visual cue
2. Post-completion error, in the form of the required clicking of confirmation buttons upon entering each value, which represented a post-completion step

In Figure 9, the sequence of data entry is represented by the numbers superimposed on the image. Participants would first select a drug (step 1) before clicking enter to confirm (step 2). Participants would then enter VTBI (in field 3), and click enter (step 4) and then repeat the entry and confirmation steps for the 'rate' and 'duration' values. Upon entering these values, participants would 'add' the entry with step 9, with step 10 simply showing an output for the previously entered drug, which participants were instructed to double-check after adding set of values.

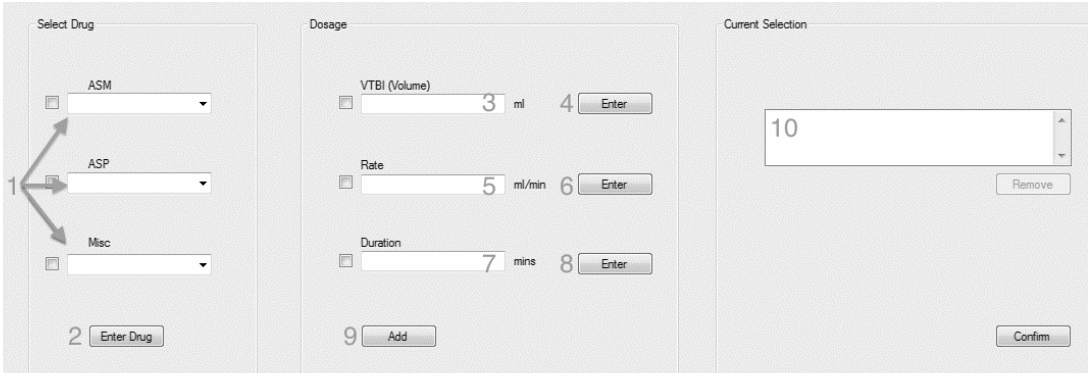


Figure 9. A Screenshot of the Task Interface taken from the Training Task

The design of the interface and input sequence was deliberately cumbersome to an extent, so as to increase the challenge presented by both place-keeping and post-completion errors. When participants returned to the interface having been interrupted and instructed to divert their attention towards the distractor task, there was very little inherent support in the interface to indicate their progress through entering a course of medication, with the exceptions of the cues (either hard-coded or user-configurable) in the two 'cueing' conditions.

Altogether there were three minor variations of the interface, corresponding to the three conditions as previously described: user configurable cues (taking the form of unpopulated, interactive checkboxes- as shown in (i) in Figure 10), system mandated cues (green ticks to assist progress tracking, appearing upon the entering of values, represented in (ii), Figure 10) and an absence of cues (represented by (iii), Figure 10). While the study had been designed in an independent samples format, negating a need to counterbalance (as would have been the case with repeated measures), we opted to alternate conditions across participants (i.e. P1: user-configured cues, P2: system cues, P3: no cues, P4: back to user configured cues and so forth) rather than sequentially completing each condition (i.e. P1-10: user configured cues, P11-20: system cues etc.). As will be discussed later in the results, this turned out to be an important detail, facilitating insights that arose early and motivated us to adapt the study and ultimately move away from these conditions.

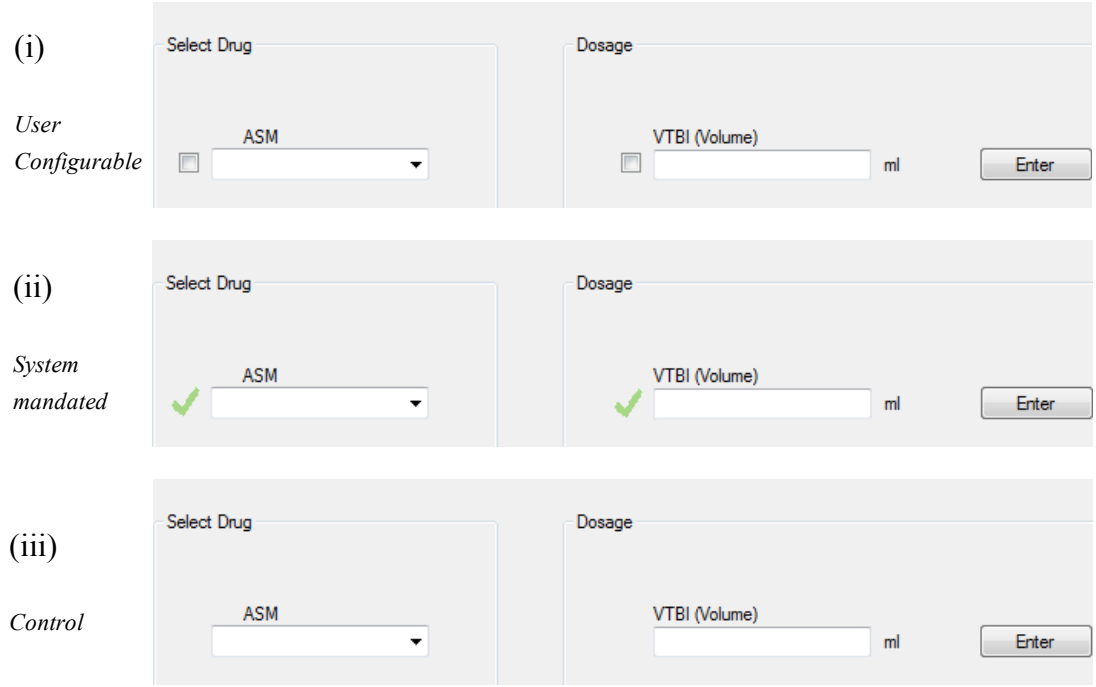


Figure 10. Close-Up Screenshots of the Different Cueing Implementations

Regarding the removal of existing implicit cues, the blinking text cursor built into Windows forms was also disabled, ensuring participants were not able to make use of this as a visual cue to assist progress tracking. Moreover, in an effort to mitigate the previously described behaviour of using the mouse pointer as an implicit cue (as observed by Back et al.), participants were instructed to use the onscreen calculator when performing checks in the distractor task, which would have resulted in the cursor being moved during the interruption and so not placed in a location where it had been previously 'left' upon task switching.

It should be noted however that the potential for the creation of basic *physical* cues was, to an extent, afforded to participants in the form of pens and paper. This was a conscious decision, motivated by the fact that in the analogous real-world task, such materials would likely be available. Crucially however, such cues were intentionally not primed (merely afforded only by the availability of the resources) and their investigation was, at least initially, considered a secondary aim, as opposed to the more detailed investigation of the controlled conditions.

Data was captured via automated logging (users' form inputs were recorded into text files which were then analysed to obtain the performance data), screen recording (with real-time monitoring and concurrent note-taking, to supplement both performance data and recording of participants' unanticipated resilience strategies), collection of paper sheets, and brief informal ad-hoc questioning upon task completion to probe participants responses to the task and any actions or behaviours which extended beyond, or deviated from, the initial instructions.

Prior to the data gathering phase of this setup, participants were also provided with standardised instructions in paper format and required to complete an interactive training walkthrough of the task. The intention of this was to familiarise participants with the task and help with comprehending what was potentially a challenging task, and to instil a rough baseline level of performance across the participants, which we anticipated based on the task-paradigm being constructed and relatively abstract, ensuring no prior experience across our pool of participants.

It is important to note at this point that in the cue configuration condition, users were not explicitly instructed to make use of the cues, rather we intended for participants to take an active role in engaging with these cues, given that their level of uptake and engagement was one of the variables we measured to address the second aim listed in 4.3. Of interest would also be the precise manner in which they did so; whether boxes would be checked immediately upon moving to a field, or upon clicking the 'enter' button to the corresponding field.

In terms of providing participants with instruction as to the configurable cues, a similar principle was also applied to the provision of the pen and paper, with participants being informed that they *may* write on any of the pieces of paper in front of them (the phrasing was designed to ensure participants were not 'directed' to do this, rather merely informed this was permitted).

When participants had successfully completed a round of data entry in training mode, they were asked to confirm that they were comfortable with the task, and were given the opportunity to seek clarification on any queries, or return to the

training exercise if necessary. Only after participants confirmed they were satisfied with the procedure, did we progress to the recorded study (data gathering) phase.

For the written guidance provided to participants, and the data cases supplied for entering into the interface, as well as the distractor task, refer to Appendix A.

4.5 Results

Notably, task performance demonstrated by participants, along with observations made of a number of other largely *unanticipated* resilience strategies, resulted in an unexpected shift in the direction of our investigation. It soon became clear that while we were not observing results in terms of cueing as we had expected, this initial investigation was to provide some interesting and rich insights into how participants resiliently managed their performance in an interrupted and relatively challenging task. In this subsection, and the discussion following, we therefore address a number of these resilience strategies and behaviours that fell outside of the narrow 'cueing-related' subset of strategies originally targeted, and the controlled paradigm we had originally envisioned.

Returning to the originally envisaged format of the study, we were initially looking to compare the performance of participants across three conditions, representing a user-configurable cue, a system mandated cue and the lack of any designed-in cueing support. Owing to the decision to alternate conditions between participants, it was possible to very quickly form an early impression of how participants were performing in each case. After 9 participants had completed the study (thus 3 participants in each of the 3 conditions), we began to observe both a rate of task performance, as well as a variety of strategies, that did not conform to our initial expectations. We had approached the study anticipating a lower rate of error for the instances where cues were present, and a higher rate of error for the control group (for which there was neither a designed-in configurable nor hardcoded cue). In actuality however, we observed only a handful of errors across the control group despite their lack of cueing support, but crucially and likely accounting for

this, we had begun to observe a variety of notable and insightful resilience strategies (which served to mitigate the particularly challenging nature of the task for the control group). Moreover, engagement with the configurable cues in the primary cueing condition was minimal, with none of the participants fully utilising these throughout their interaction with the task, and an error rate slightly *higher* than that of our control group.

At this point, it had become clear that performance data was not in line with expectations, but crucially also that it would not be feasible to draw meaningful performance (error) comparisons between the conditions for two reasons;

(i) participants were not engaging with the configurable cueing element we had introduced, and which formed the primary condition we sought to assess, meaning we could not study performance effects of user configured cueing

(ii) particularly in the control condition, participants were demonstrating the ability to bypass the intended controls and counteract the lack of cueing support, by introducing their own ad-hoc strategies and behaviours. This removed consistency in the inherent nature and difficulty of the task at hand

While judging the outcome from these early cases by performance alone it was clear the study would not be able to deliver on its intended aims, the majority of participants in the control condition however were developing innovative, often unanticipated and novel strategies that appeared to provide far more insightful material for analysis, and indeed served to shape the future direction of the thesis. Owing to the limited insight we were yielding from pursuing the performance data we had originally set out to collect, and owing also to the exploratory nature of this probing study, it was at this point that we opted to adjust the study setup while the study was still in progress. Rather than persisting with the three conditions, between which we would be able to draw few if any meaningful comparisons, we opted to cease the collection of performance data and errors, and instead redirect attention

towards the novel and creative strategies participants were utilising to overcome the challenges designed into the task scenario. As these were primarily occurring in the control condition (owing to its lack of inherent cueing support), we opted to run the remaining participants through the control paradigm, and to redirect our attention to what was emerging as the real fruitful and insightful output of the study. This shift in emphasis, away from a close focus on cueing alone, instead enabled us to capitalise on the broader variety of manifestations of resilience that were being observed, and this became the sole ultimate focus of the study.

A total of 45 instances of what was considered to be potential resilience strategy or behaviour use were observed across the full sample, however given that many of these comprised only minor variations from each other, there were grouped into five key types, based on common themes or threads derived during their observation. Each of these is outlined here but discussed in more detail in 4.6, the study discussion, following.

Momentarily Deferring Interruptions

A total of 14 participants were observed to momentarily defer interruptions. The interruptions within the study took the form of intervention by the experimenter, with an instruction for participants to stop working on the primary task and proceed with the secondary distractor task. While in the instructions, participants were requested to do this immediately, in 14 cases participants would circumvent this aspect of the paradigm by ignoring this request and continuing to progress with the primary task with which they were engaged, effectively suspending the interruption, albeit only for a few seconds at most.

Creation of Physical Cues or Artefacts

A total of 13 participants were observed to use the pens and paper provided in order to generate either physical cues or artefacts to assist with their progression through the task, generating annotations, notes or other markings as external physical denotations to track progress or provide other assistance, as in Figure 11.

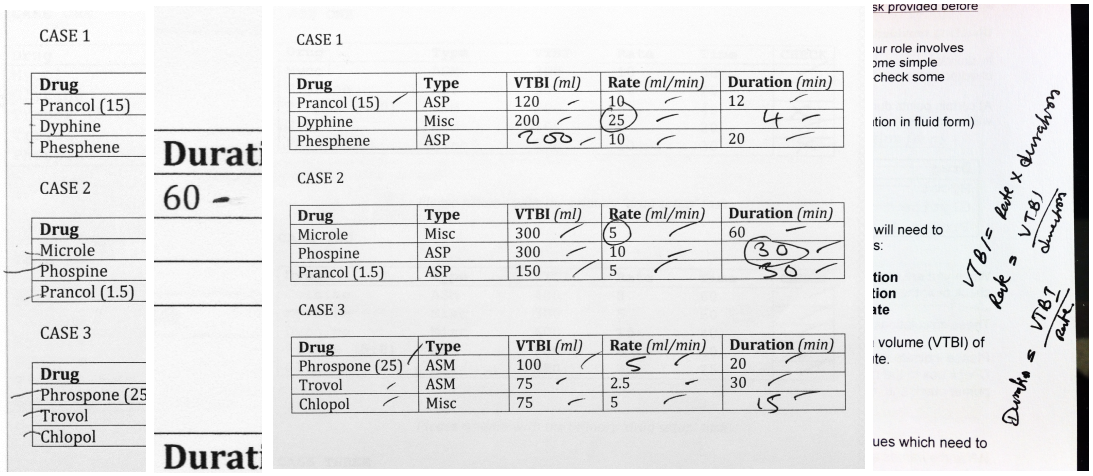


Figure 11. Some Examples of Improvised Cues and Artefacts

These varied in form, from marking each row of items as processed, to marking only the individual item affected in the case of an interruption, to marking each and every item individually, as reflected by the first three examples in Figure 11. This creation of physical cues to assist in placekeeping represented 7 of the 13 instances observed. Also included in this category were annotations made to the instruction sheet in some cases, for example the fourth item in Figure 11, and such ad-hoc notes represented the remaining 6 instances.

Restructuring Task Sequence or Data Entry

A total of 11 participants were observed to restructure the task structure, or the order in which data was entered into the system, in defiance of the instruction initially provided. In so doing, they displayed the type of subtask boundary manipulation described, for example, by Iqbal & Bailey (2006) and further discussed in 3.4.4. This comprised two primary behaviours;

(i) performing all of the calculations on paper first, before proceeding to enter all of the data into the system (as opposed to the instructed sequence of completing sets one at a time and thus completing calculations during the data entry)

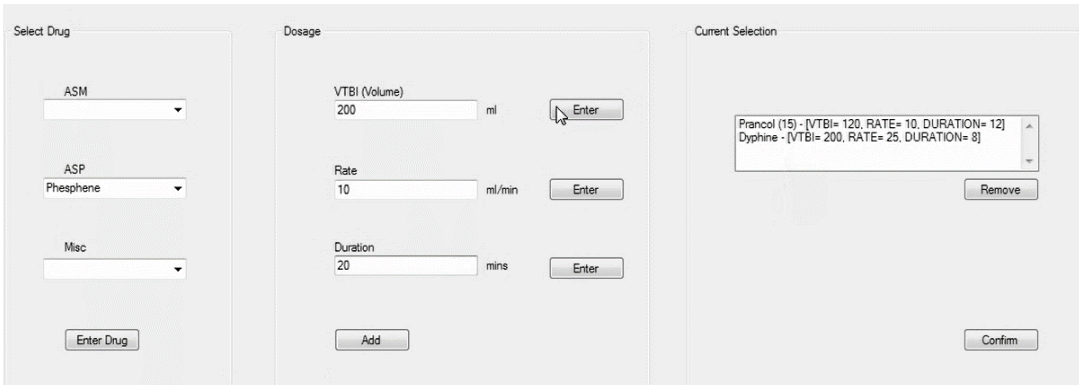


Figure 12. An Example of 'Task Restructuring'

(ii) populating each field in the form *without* confirming values (clicking the corresponding 'enter' button) until a set was fully inputted, before then sequentially clicking all of the 'enter' buttons together.

Figure 12, above, is a screenshot showing a participant having employed the second of these strategies. The task instructions and training exercise requested for participants to enter each field, upon which the field would be returned to a blank state, thus were this procedure to have been followed according to the original instructions, only one of these fields would contain a value and not all four.

Other On-Screen Cueing Implementations

A total of 3 participants each developed and utilised strategies leveraging the limited on-screen items in order to track progress when presented with an interruption. Two participants replicated a behaviour previously described by Back et al. (2008) whereby they placed the mouse cursor in the field corresponding to their next point of interaction post-interruption. This was identified as a deliberate operation in both occurrences during post-hoc questioning by the experimenter.

Figure 13. Examples of Improvised On-Screen Cues

The final participant deploying a strategy also falling into this grouping, whereby upon receiving an interruption, the participant effectively 'mashed' the number pad on the keyboard to quickly populate a field with a string of zeros to serve as a visual cue indicating the field they were to resume from.

Verbal Rehearsal to Assist Working Memory

A number of participants (recorded at the time of the study as 6 in total, but likely to be a higher number as this was only noted mid-way through the study, and any prior occurrences were not available from the data collected) were also seen to display a resilient behaviour in the form of verbal rehearsal. This is a topic we describe in more detail previously in 3.4.5, whereby information is repeated verbally and audibly in order to increase the capability to preserve it in working memory (a topic explored in more length by Lucidi et al., 2015).

In the discussion that follows, we evaluate the approach adopted and critique some of the specifics of the task paradigm that was designed, and further discuss the motivations of the shift in emphasis of the study, before returning to consider the above strategy groupings in more detail in terms of how and why they were realised.

4.6 Discussion

In order to understand why the study progressed in the manner as described, it is important to revisit the unanticipated aspects of participant performance we observed, and discuss some the limitations in the design and implementation of the task paradigm that were responsible.

With regards to task performance, while our observations here are based across only 9 cases, it is notable that a significant level of individual variation in terms of task performance between participants was initially evident (with total errors per participant ranging from 0 up to 13 in the 9 across the 9 participants for which error rate was recorded). This proved to be much higher than expected, and rendered it unfeasible, given the limited sample size available, to establish a consistent reflection of performance for each of the three groups. Informal post-hoc questioning of participants upon completion of the task also reinforced this perceived variation in difficulty, with some participants remarking upon how straightforward they found the task and others describing it as particularly challenging.

This essentially means any observable trends in performance data would more likely have been the result of individual differences (particularly given how some participants were circumventing controls with their strategies and behaviours while others were not) rather than a consequence of the condition they were in. Whilst we do not have explicit data to inform precisely why this occurred, based on some brief accounts by participants and on reflection in hindsight, we speculate that this may be a reflection of natural variations in participants' confidence or competency in performing mathematical calculations, a topic that was also volunteered by several participants during our post-hoc questioning with them.

Another motivation for adapting the target of our study was the low level of engagement with the configurable cue we had introduced. Of the three participants who progressed through that interface, only two participants made use of the cues, however of these, one participant used the cue only once, and the other for only one set of entered data (i.e. not for the majority of the task). To our surprise, and in a step

which mitigated the necessity to adopt our configurable cue, all three participants in this condition actually made use of additional and unforeseen resilience strategies as described in the groupings in the results section above.

This latter point brings us to consider that while our initial intended target of investigation, the performance implications of user-configured cues, was not ultimately realised, the study did however provide us with a rich and varied picture of a variety of resilience strategies. It is perhaps an encouraging facet of human performance that rather than perform poorly in the task, the challenging circumstances of the task paradigm we introduced (in particular, in the control condition) conversely elicited a variety of improvised, ingenious performance-maintaining strategies and behaviours. Ironically it could be said that this work, looking at the resilience of individuals, did not proceed as anticipated or hypothesised *precisely because* of just how resilient our sample was!

By shifting the focus of the study, we have been able to move beyond merely demonstrating the resilience of individuals, but to also identifying and specifically considering a wider variety of strategies and behaviours that users deploy to achieve greater resilience. We move here to considering the five identified groupings of strategies in more detail.

Momentarily Deferring Interruptions

The most frequently observed type of strategy across participants was their propensity to redefine the task structure, or to 'micromanage' the nature of interruptions. This took the form of participants momentarily ignoring instruction to move from the primary task to the distractor task in order to either defer the disruption and complete the 'unit of work' or achieve the sub-goal they were currently engaged upon, or else even to temporarily generate a cue in some cases, in the primary task. The lengths of time that participants deferred these interruptions by inevitable varied but at no point lasted more than a few seconds, yet even this fleeting operation allowed participants to vastly reduce the threat of post-completion errors.

The point at which interruptions were delivered was predetermined and carefully considered prior to the setup of the study, in some cases in order to maximise disruption (e.g. midway through tasks, while participants would have to be engaging their working memory). Interruptions were originally intended to be automated onscreen, however due to practical and technical constraints in implementation, they were ultimately administered by the experimenter based on real-time observation of progression through the task. While this provided arguably a decreased level of control, it was considered more naturalistic and representative of the majority of instances of interruptions in real world tasks (rarely is an interruption so salient and rigid as to literally force immediate action). What was unanticipated was just how frequently users momentarily deferred the interruption in order to offload their working memory in the primary task (e.g., in order to complete an arithmetic calculation and record the output value in the form).

Crucially, the above behaviour was unforeseen largely because it has not, to our knowledge, been discussed within the context of existing literature into resilience strategies. Owing to the fact that this is a relatively commonplace behaviour and, upon consideration, can be applied in a limitless range of contexts, the fact that it has not been articulated in any of the work focussing on individual resilience is surprising.

However, upon retrospective review of a broader pool of literature after undertaking this study, it emerged this behaviour is indeed explored and articulated, however in other fields and not under the guise of resilience. Iqbal and Bailey (2006), for example, provide gross examination of the cost of interruptions and the implications of interrupting users at various points in the progression of a structured task, as we subsequently found and have detailed in the literature review above).

The nature of the strategy, and the varying extent to which is was a conscious and deliberately employed behaviour (as opposed to a more natural or even ‘automatic’ aspect of behaviour when interrupted) has implications for how we conceptualise what resilience strategies are, a topic we revisit later in Chapter 7.

Creation of Physical Cues or Artefacts

To an extent, the creation of physical cues and artefacts was less of an 'unanticipated' strategy and indeed we intentionally made provisions for this by ensuring pens were available and instructing participants that the sheets of paper in front of them could be written on. We did not, however, anticipate the frequency with which this would be observed, nor the number of variations we saw in terms of how this would be realised.

In a broad sense, the scribbles and notation added to the pieces of paper could be said to fall into two categories;

(i) annotation being added to the instruction and training sheet
(ii) markings made during the conduct of the task scenario for placekeeping

With regards to the former of these, a total of 6 participants added annotations to the training and instruction sheet (representative examples of which are shown in figure 14). In 4 cases, participants reformulated the format of the equation between the *VTBI, Rate* and *Duration* values, adapting it into a more 'graphical' representation than that already provided in the instruction sheet, presumably in order to assist with comprehension and the ease with which this equation could be referred back to if required.

Other examples of annotation to the training and instruction sheet involved underlining and circling perceived key pieces of information (the numerical values in a passage of text, and the summary of the equation necessary to complete the task) to again assist with comprehension and perhaps improve the 'glanceability' of the text.

In each of these cases, these annotations facilitated understanding and comprehension of the task upon initial instruction and training, adding personalised clarity where deemed necessary by the participants. By supplementing the instructions with additional annotation, an 'enriched' artefact was formed which could additionally be consulted more efficiently during the actual conduct of the task if required.

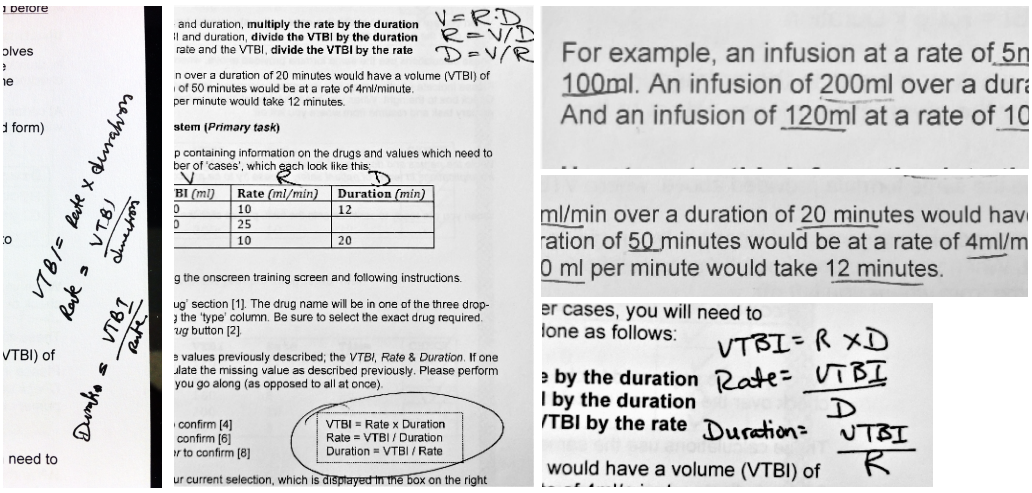
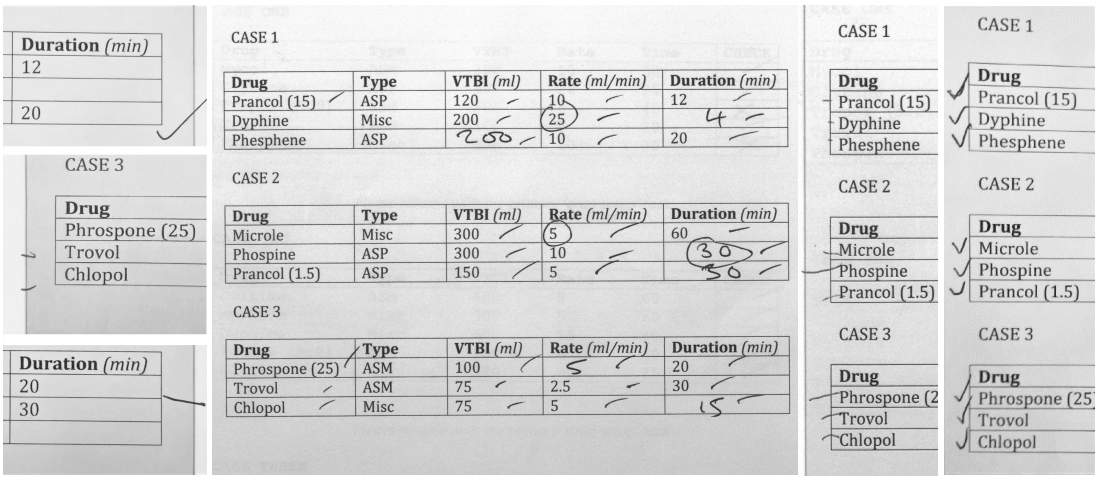


Figure 14. Ad-hoc Notes to Enrich the Training Sheet

In addition to these annotations that were observed prior to the study formally commencing, a second variety of physical annotations participants made were to the materials used in the conduct of the study itself. The common thread in this second grouping was in their purpose, in terms of placekeeping and managing the disruptive effects of interruptions during the task itself. This ironically represented the principle that we had originally set out to study, however comprised a different manifestation of it, in that it was a type of cue-forming behaviour but perhaps a more immediately approachable and tangible version of it than had been incorporated into the interface of the system itself.

There was some variation in how participants achieved this, which ranged from very minimal dashes/lines or ticks being added at a point of interruption (as seen in (i) in figure 15) to more extensive annotation at every available opportunity (as seen in (ii) in figure 15). Other examples of this fell somewhere between these two ends of the scale, for example marking 'lines' or ticking where a full case had been completed (representative examples of which are in (iii), figure 15). Therefore, while the cases in this grouping appear similar in terms of what is observable from the paper sheets collected, there is some subtle variation in terms of the nature of the strategies, that we expand upon in the discussion.



(i) (ii) (iii)

Figure 15. Cues Used to Assist Placekeeping

In (i) above, we see three examples of limited annotation taking the forms of a tick, and some short dashes or lines. In each of these cases, while the figure shows only a small cropped view of the sheet, these marks were the only annotations made by each participant. While we did not employ either a 'thinkaloud' or collect video recordings to be able to validate this, it appears in the first case the tick has been used to signify the completion of a case, while the dashes were used as placemarkers upon interruption. In the latter cases, it is possible that these cues may be placed either on the 'last action taken prior to interruption' or 'next action to take upon resumption'. We did not, however, capture sufficiently rich detail (for reasons later discussed in 4.7.2) to conclusively verify which of these cueing variations was undertaken here.

In example (ii) above, the participant can be seen to have developed an ad-hoc procedure whereby each item was marked upon being consulted, and the circles in this case represented points of interruption. Adopting such a meticulous approach meant that the participant enabled full traceability as they proceeded through the task, which in turn facilitated the process of checking back over their working. The process of checking, while not identified at the time, in hindsight could itself be seen

to represent an additional form of behavioural resilience, a consideration we articulate in more detail in the following chapters.

The examples shown in (iii) represented something of a 'middle ground' between (i) and (ii) in terms of the complexity of implementation. In these cases, as a participant completed a full 'set', represented by a row of the table, this was denoted by generating a cueing annotation. The 'fidelity' of this approach ensured that participants did not have to repeat entering sets (rows) unnecessarily upon resumption, but did not contain sufficient detail (i.e. by marking individual numbers within a row) to resume from *exactly* the point of interruption if they were mid-way through a row. This limitation could however have been mitigated if participants combined this strategy with the deferral of an interruption, to reach the end of a row.

It could be argued that there was a trade-off in these cueing implementations, as the use of an extensive scheme of marking (demonstrated in (ii)) added to the time and effort invested in the task, while a strategy such as (i) represented the quickest way to generate a cue, but lacked detail which may later have been useful, for example if checking values upon completion.

One point to reflect on is the extent to which the two 'subtypes' of strategy in we have paired into this item are suitably combined. For the purpose of accurately reflecting the ad-hoc notations of the experimenter in the actual study, these two threads have been presented here as grouped. This was based on their observable similarity in both utilising the pens and paper that participants were provided with. However, the grouping of these two threads becomes weaker if one considers the motivations for each approach, and the 'threats' which each mitigated. The resulting annotations also could be said to fundamentally differ, with some of the notes added to the instruction sheet containing purposeful semantic information, while others such as dashes and circles to track progress, serve merely as cues to direct attention and contain no semantic information in and of themselves. This raises questions with regards to how resilience strategies may be considered conceptually similar, and demonstrates how two behaviours which are comparable in observable terms may

each serve a differing purpose. This is a consideration we moved to consider in far greater depth later on, and is reflected upon particularly in Chapters 5 and 7.

Restructuring Task Sequence or Data Entry

Another grouping of observed strategies or behaviours involved 'restructuring' the task, in terms of the sequence of operations necessary for task completion. As with the above grouping of cue and artefact creation, this again could be said to be divisible into two observably differing noted approaches:

(i) Completing and noting the calculations first, prior to attending to the screen
(ii) Adapting the sequence of data entry into the onscreen form

The former was in hindsight a relatively straightforward manner in which it was possible to simplify the task, fundamentally changing its nature. While the task as envisioned required multitasking between calculation and data entry, participants who used this first strategy subdivided these operations and recorded the calculated values onto paper prior to attending to the onscreen portion of the task (represented *left* in Figure 16). This resulted in the completion of calculations in one 'block', rather than interspersing these with data entry as had been originally instructed.

This could potentially be advantageous both in terms of reducing the potential for error (as attending to one task individually improves task performance (Wickens, 1992), and/or increasing efficiency (as attending to tasks sequentially was a more efficient approach than multitasking). Owing to the original framing and purpose of the study however and its focus on error rates as opposed to the nuanced intricacies of motivations for resilience, such a distinction had not yet to be identified at the time of the study, meaning we cannot conclusively assert whether one of these was the prevailing motivation for adopting such a strategy, or whether both were considered.

The second type of strategy noted from observing participants complete the task was in their adapting the sequence of completing data entry into the onscreen

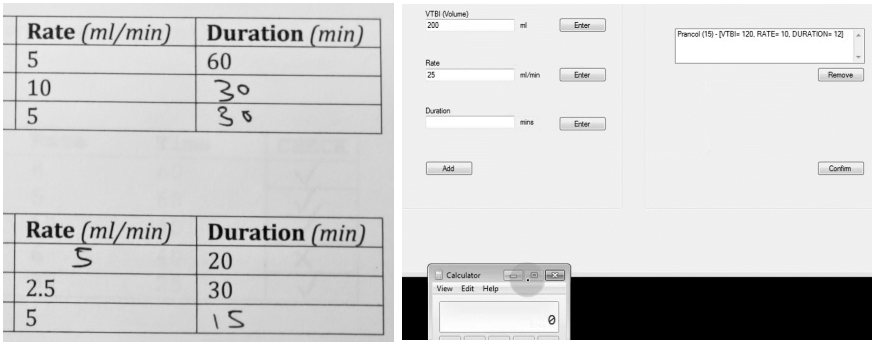


Figure 16. Two Examples of Restructuring Sequence

form interface. The primary threat designed into the task was that of a memory slip during task resumption, upon completing a portion of the distractor task. This represented a significant challenge if participants precisely followed the task sequence set out for them during the training and instructions. Some participants however circumvented this by entering text into all values of the form before clicking the 'enter' buttons. Since the enter buttons were designed to clear the contents of the corresponding fields, this meant that where participants entered values in multiple fields while averting the 'autoclearing' action, they could track their progress by noting the last value entered upon task resumption (as shown above, *right* of Figure 16). The values entered into fields themselves therefore became an implicit visual cue to assist placekeeping. Participants engaging in this behaviour therefore had little need to utilise any further onscreen cueing implementation, however such a strategy could not mitigate the disruptive effects of an interruption mid-calculation.

A small number of participants combined both of the above approaches, which meant that the structure of the task they completed was fundamentally different from that intended, and that which other participants experienced. Rather than being a case of *calculate, write value into field, click button to enter (with field subsequently clearing), move onto the next case and repeat*, the task became *perform all calculations in one go, fill in all fields within the form, click all enter buttons*. The inherent way in which this fundamentally changes the nature of the task again

represents a reason why proceeding through the study as it had originally been envisioned, and recording error data, would have been of very limited insight. It would not be appropriate to compare the performance of participants who had circumvented controls to give themselves an 'easier' task, with participants who had instead fully followed the instructions provided and thus been subjected to a 'more difficult' task.

Other On-Screen Cueing Implementations

A small number of participants were able to form cues to assist with placekeeping using only the very limited resources available onscreen (represented in Figure 13, in 4.5). This again manifested in two distinct methods that participants enacted;

(i) Intentionally positioning the mouse pointer to repurpose it as a cue, and
(ii) Entering a string of 'nonsense values' into a field to form an ad-hoc cue

As noted previously, we identified the potential for the mouse pointer to be appropriated as a cue from previous work by Back et al. (2008). We attempted to mitigate this possibility of this occurring within the design of the task by encouraging participants to use the onscreen calculator as part of their completion of the distractor task, which would have necessitated moving the pointer away from the onscreen form, and thus it not being available to repurpose as a cue. Some participants however were able to perform the distractor-based calculations mentally with relative ease, meaning they did not require use of the onscreen calculator. For participants who were able to do this, the option of utilising the mouse pointer therefore again became available, and was noted in two cases.

In both cases, participants pointed the cursor at the next operation to be completed upon interruption, enabling them to 'pick up where they left off' without the need for any additional cueing support onscreen. While this represented a rather 'subtle' cueing behaviour and could also have occurred by chance (i.e. with the

participant being interrupted immediately upon having already moved the mouse cursor) we were actively looking for such a behaviour based on the observations of Back et al., and were able to verify that this was enacted consciously and intentionally by directly asking participants whether this is something they had done, upon their completion of the task.

The second behaviour we included within this grouping was employed by only one participant, but still represents a noteworthy and somewhat ingenious tactic to generate a cue in an onscreen interface that otherwise provided very limited support for cueing. The participant in question, upon being interrupted, entered keystrokes into the field they were working to complete, knowing that the values placed into the field were incorrect and not to be entered, but they still formed a cue to signify the field they were working on which could be used for placekeeping upon resumption from the distractor task. This was verified as an intentional behaviour, enacted for the purpose described here, again in brief questioning of the participant upon completion of the study, to ensure that the observation was not instead the result of a 'typo' or accidental keystrokes. The form of the cue therefore becomes comparable to the strategy whereby participants altered the sequence of data entry into the onscreen form, since in both cases, fields were populated with values for the purpose of placekeeping, however the observably different way in which the participant achieved these same ends without altering the structure of the task motivated us to consider this strategy separately.

Verbal Rehearsal to Assist Working Memory

A further behaviour participants displayed to enhance their resilience and cope with the threat presented by interruptions, was in using verbal rehearsal. While we recorded 6 instances in which this was observed, this strategy was potentially more prevalent than that number would suggest, as this was a behaviour we only articulated and began to note mid-way through the study.

Verbal rehearsal, as discussed in the second chapter of our literature review, is the process of repeating information out loud multiple times, utilising the

phonological loop in order to preserve the contents of working memory. In the study here, this took the form primarily of repeating numbers out loud when interrupted during the calculation task, meaning that upon completion of the distractor task, participants did not have to repeat the calculation they were processing from the beginning. In one noted case however, this was also used to assist with placekeeping during data entry into the onscreen form, by repeating the title of the next field to be completed. In all noted cases, participants' vocalisations were quiet and done 'under their breath' rather than loudly speaking, though this may have been a result of the demand characteristics of being under observation during the study, and participants not wanting to be seen to explicitly 'talk loudly to themselves'. A brief and informal probing conversation with participants upon completion of the task revealed that some participants were aware they were saying these values out loud, while others were not conscious they were doing this at the time it was observed.

Picking up on this last point, the observations noted in this study caused us to pause and reflect on a potential distinction between *strategies* and *behaviours*. There is a discussion to be had concerning the 'intentionality' of resilience, and the extent to which behaviours which may be subconscious or 'automatic' comprise resilience strategies, even though they may clearly be enacted to counter challenges or threats, and consequently result in enhanced performance in a resilient manner.

This directs us back to the topic of how we frame resilience that was discussed in the literature review (2.3) and the extent to which resilience *as an automated or subconscious action* constitutes resilience proper- or whether it is best considered as 'something else'. To date, we note that cases such as these have seemingly not been articulated within the context of work into individual resilience in the literature specifically targeting resilience strategies. The mere fact that these behaviours were observed here in itself does little to address this fundamental question. It does however highlight that it is of relevance, and that users do act in a way that improves their performance and in some cases, do so near autonomously. Whether or not instances of this are truly resilience is currently a matter of perspective, however as we make clear in 3.5, we consider that there is potential

value in carefully considering these within the scope of resilience strategies and behaviours.

In addition to exploring the types of resilience strategy observed, another immediate and interesting feature of this work was what *motivated* participants to deploy these strategies. Again, as the prevalence of these strategies was an unanticipated outcome, such motivations were not in and of themselves an explicit aim of this study. As such, we did not have the opportunity to collect sufficiently rich data to capture all of these strategies, and nor did we have a structured method in place to explore the intricacies of these strategies in quite such a fine-grained level of detail. One adaptation we did however make upon shifting the target of the study was to administer brief, ad-hoc questioning of participants in cases where immediate clarification could be sought. It emerged that participants by and large simply undertook these practices as a direct consequence of the challenging nature of the task at hand- they had been given the opportunity to assess the level of difficulty of the task in the training session and reflecting on this, had adapted their behaviours in order to maintain performance. In the majority of cases, this was emphasised explicitly upon probing, however as described above, some participants were less able to reflect back upon and articulate their in-task behaviours, and in some cases could only speculate on the reasoning behind their observed practice owing to the retrospective nature of the questioning, and the lack of instruction to reflect upon resilience during the conduct of the tasks.

4.7 Evaluation and Contributions

This closing discussion revisits two key evaluative points of the study, in the form of (i) individual variation in performance and how pitching the difficulty of the task proved to be of crucial significance, and (ii) approaches to the collection of data and what we have learned about potential future opportunities to better capture resilience. We close by going on to highlight the contributions of this work and how it may serve to inform future investigation.

4.7.1 Task Difficulty and Variance in Performance

Considering the methodology of this study and evaluating the implementation of the task apparatus, an immediate potential oversight can be identified that only revealed itself with the benefit of hindsight: a significant variance in perceived difficulty and subsequent performance. While the task was sufficiently artificial so as to be deemed 'new' to all users (thus it was reasoned, baseline performance would roughly be even across participants as none would have pre-existing expertise coming into the study), the nature of the instrument and wider task in fact provoked very different responses from participants. As noted, upon completion some participants remarked that they found the task to be very easy and others indicated that they found it extremely difficult. Given the limited sample size available, a reliable baseline level of performance by which to compare responses would have therefore been impossible to obtain; the individual differences were too great.

While there is not sufficient information available to conclusively determine exactly why this significant variety in performance occurred, based on participants' reflections upon the task and their perceived performance, we speculate that this was in large part a reflection of natural variation in participants' comfort and competence in numeracy. Both the primary and distractor tasks involved calculation, and it was noted that some participants completed such exercises with relative ease using mental arithmetic, while others relied heavily on the provided calculator and appeared to find this aspect of the task more challenging. This point is of particular note as the participants who had no need to use the onscreen calculator were at an advantage, for the placement of the mouse cursor was available as an implicit cue, as previously discussed.

We can again only speculate here but we suggest the possibility that *perceptions* of difficulty when approaching the task perhaps also played a role in the variance of performance. participants were required to manage values with unfamiliar titles (e.g. the names of the drugs, their introduction to the concept of

VTBI or volume to be infused) and the very technical nature of the instrument meant some participants found the task daunting (or even "intimidating" in one case) from the outset, which we feel may in itself have had a detrimental effect on some participants' performance levels.

One might justifiably suggest that a more thorough piloting of the task paradigm and apparatus might have revealed the potential for this variance in performance, and this is a point we concede could be the case. At the same time however, it is worth noting that owing to the study being an initial probing study, the paradigm being relatively challenging and 'involved' and thus the size of the sample being relatively limited, to pilot with more than the 3 individuals with which we did (more than 10% of the final sample size) could justifiably have been deemed an unwise use of time and resource, given practical constraints (primarily in terms of time and cost).

4.7.2 Approach to Data Gathering

One aspect of the investigation we must also acknowledge concerns the approaches used to gather data during the study. As explained, the direction and purpose of the investigation shifted mid-study once we recognised that we would be unable to meaningfully investigate the performance effects we originally sought to, while at the same time we saw a clear opportunity to extract key insights into a broader variety of other resilience strategies and behaviours. This did however impact the ability we had to record and examine such strategies in minute detail, as the investigation had originally been designed and framed to capture a different 'type' of data in the form of errors.

Reflecting back upon the approach used to gather data, and with the benefit of hindsight and a focus on capturing more rich accounts of resilience strategies, it would have been beneficial to incorporate video recording of participants' conduct and a more structured post-hoc interview in particular. These inclusions would have enabled a more detailed retrospective analysis of strategies and behaviours, as well

as provided a deeper understanding of the motivations participants had for executing strategies (which would have been particularly helpful for disambiguating cases where it seems multiple alternative potential motivations could be inferred).

While the screen recordings and paper sheets we obtained do provide some concrete material for subsequent analysis, these were supplemented with only ad-hoc notes based on observations and informal brief post-task questioning to clarify some aspects of behaviour or strategy use. This supplementary information, resulting from the redirected focus of the investigation, serves to add detail and increased the total number of captured strategies. While video-recorded observation data, and the recording of formal retrospective interviews would have resulted in a more rich and robust approach, it is worth remembering that these features would not have been necessary or valuable to the original purpose of the study as it had been envisaged, and the possibility of introducing them mid-study was not available as the required ethical approval had not been sought for the collection such recordings.

The study described in this chapter therefore contributed not only a broader and more interesting collection of strategies than intended (which significantly shaped the direction of the PhD following) but also provided valuable practical lessons in terms of how to capture, record and consider both the variety and more detailed intricacies and nuances of resilience strategies and behaviours. This clearer picture of how to study resilience in subsequent investigations is something that benefited the investigator, and is applied and capitalised upon in the later controlled study described in Chapter 8, and further discussed later in Chapter 9.

4.7.3 Contributions of the Study and Implications for Subsequent Work

Owing to the fact that that we ultimately moved away from the original intended primary objective of this initial study, one might quite reasonably deem the study to be far from a success. While if considered in the context of its initial premise this holds true, retrospectively we see great value in some of the insights this

first probing study provided, and reflect here upon the fact that the findings we made were pivotal in shaping the subsequent direction of the PhD.

Perhaps the primary finding of this investigation, which does indeed address one of the key original aims of the study, is that resilience strategies are readily observable and can indeed be elicited even within the confines of a relatively tightly controlled paradigm. While participants did not conform to our expectations regarding the specific cueing strategies we envisioned, participants demonstrated a far broader remit of strategies and at a greater frequency than we had anticipated. Moreover, upon attempting to situate these observed instances of resilience within the existing topical literature, we seemingly identified some resilience phenomena that were thus far either unaccounted for or not clearly articulated within targeted literature addressing personal resilience in a HCI context. These included strategies to momentarily defer interruptions, restructure subtask sequence and workload, and verbal rehearsal to facilitate working memory.

Our observations also raised questions about the nature of the concept, in terms of the extent to which resilience *behaviours* (which we conceptualise as resilient interventions that users develop or deploy at a subconscious level, such as verbal rehearsal) constitute the resilience *strategies* as defined in the existing literature. The fact that some of these concepts have not been discussed within the context of resilience in HCI also lends weight to the assertion previously described in the literature review that our understanding of the breadth and variety of phenomena that make up resilience is not yet comprehensive or fully-formed.

The study also provided valuable experience and lessons with regards to the conduct of controlled studies targeting resilience, in terms of pitching the difficulty of tasks (and by extension, more carefully considering the nature of such tasks), and attempting to scope or control-for resilience. These are lessons which we apply directly in a subsequent follow-up study later described in Chapter 8.

Returning to the research questions and contributions outlined in Chapter 1, the current study is of direct relevance (though partially addressing, rather than comprehensively) RQ3, concerning the processes and approach that can be used to

study resilience (1.2.1). Consequently, the study also forms a limited part of our fourth contribution in terms of identifying such techniques and approaches. The study also indirectly moves us towards an enhanced understanding of what might constitute a resilience strategy, RQ1, and contributes to the pool of recorded and articulated resilience strategies providing material for analysis we conduct in the following chapter, thus forming a part of our first contribution (1.2.2). While none of the research questions are fully accounted for within this chapter, nor none of the contributions entirely fulfilled, the study helps us form crucial parts of addressing these which, when combined with the work presented in future chapters, serves to enhance our understanding both of approaches towards the study of resilience, and of the phenomenon itself.

Ultimately, this study revealed some of the limitations regarding current understanding of the topic, and expanded the scope of the PhD significantly. In terms of immediate progression from the study, our attempts to account for and reconcile our observations with existing foundational frameworks on the resilience of individuals in a HCI context lead to a contribution in developing and refining those very theories and frameworks. This is a unit of work we discuss in the following chapter.

Chapter 5: On the Expansion and Refinement of a Categorisation Scheme

5.1 Chapter Introduction

In the previous chapters, we established there was a need for a structured account of the types of resilience strategy that exist, both from a review of the literature, as well as our own experience in attempting to analyse and make sense of resilience strategies encountered first-hand from the study presented in Chapter 4 above. Furniss et al. (2012), as previously described, provide us with an early framework for this in the form of their 7-item scheme for categorising strategies, however upon application we found that there was still work to be done in expanding the coverage of, and reducing ambiguity in the scheme.

This chapter describes a unit of iterative, conceptual work that serves to develop, assess and refine an expanded scheme, which captures the variety of strategies that exist independent of specific tasks and settings. As with the original version of the scheme proposed by Furniss et al., this work serves to articulate these strategies, and group them based upon recurring underlying themes and patterns in their make-up, in an attempt to yield insights into this previously underexplored and expansive topic.

The chapter summarises work conducted over the course of many months, and is informed not only by examination of existing literature around the topic and the results of the aforementioned initial exploratory study, but also a multi-stage and iterative diary study to collect supporting instances of strategy use. As a presentational step to ensure this conceptual work is not entangled with the practical diary study work, discussion surrounding the diary study aspect of this work is presented in the following chapter.

5.2 Disclaimer on Collaboration and the Contributions of Others

It is important to explicitly acknowledge here the significant contribution to this particular unit of work by colleagues on the CHI+MED project, primarily *Dominic Furniss* and *Jonathan Back*, two of the authors of the original scheme.

The work described here builds directly upon the 2012 scheme originally devised by these colleagues, and I have been fortunate to be in a position where I am able to work in tandem with the original authors of the scheme. Given the circumstances (proximity to these researchers, owing to their participation in the CHI+MED project), it would have been, at best, a missed opportunity to attempt to press ahead with this work alone. Working in concert with the original authors of the scheme also provided a unique and invaluable opportunity to build upon their foundations and learn, through extended discussions, some of the intricacies and nuances that exist in the scheme, and concepts contained within.

As a consequence of this collaboration however, it is necessary make clear here that there is a strong element of 'shared ownership' to this unit of work, and in particular to the resulting artefact; the revised iteration of the scheme. To describe exclusively my own individual contributions and components without situating these in terms of this collaborative work would however not be practicable, and would risk resulting in misrepresentations. Therefore, in addition to this disclaimer, we will attempt to emphasise 'in-line' during this chapter where work has been conducted collaboratively, or where contributions can be attributed primarily or solely to the thesis author. To remain consistent with the rest of the thesis, as outlined in the introduction use of the term "we" will still be used to refer to the primary thesis author, while "the group" will be used to indicate work that has been undertaken collectively with colleagues.

5.3 CHI+MED Workshop on the Development of the Categorisation Scheme

Following on from the aforementioned probing study, discussions were untaken with the original authors of the scheme regarding the 'completeness' of the scheme, and the opportunity for further development. The original authors reaffirmed that the version of the scheme presented in their 2012 publication, as is noted within the paper itself, could be considered as a 'work in progress', and that they would be keen to see the scheme further developed. While both Dominic Furniss and Jonathan Back were at this point now engaged in work that primarily addressed other topics, both authors were also keen to revisit the notion of resilience strategies and actively participate and contribute to this work.

After recognising the need to develop the initial scheme, the group opted to conduct a workshop at an upcoming CHI+MED team meeting, with a view to collaboratively assessing and validating the scheme. While the original authors had previously run a similar workshop, the thesis author was pivotal in instigating this follow-up workshop as part of the CHI+MED meeting, and played a significant role in the practical running of the workshop as a facilitator, as well as naturally contributing to the workshop discussions on the day, and subsequent analytical work.

The workshop was conducted on the afternoon of June 5th, 2013, and formed part of the annual CHI+MED team meeting for that year, which was located in Melton Mowbray, Leicestershire, England.

5.3.1 Workshop Participants, Format and Exercise

Workshop co-organisers and facilitators comprised Dominic Furniss and Jonathan Back (two primary authors of the original 7-item scheme), and the current thesis author. The additional workshop participants comprised a group of 8 researchers attached to the CHI+MED project, who had been recruited to the workshop via email discussions and a whole-team orientation session describing the purpose of the workshop, on the morning of the event prior to the workshop itself.

While levels of familiarity with the concept of Resilience Strategies varied, all participants had at least a passing knowledge of the concept, while at least two of the additional participants had previously co-authored publications addressing aspects of the topic. During the introduction to the workshop however, the concept was again defined and described to all participants, together with the intended aims and format of the workshop.

The workshop was organised with the primary aim of generating a pool of examples of episodes of resilience across a broad variety of tasks and settings, and then applying the principles of the original scheme to this data and exploring and discussing the process, and in particular the 'edge cases' upon which there was some ambiguity. Where appropriate, additions were made to the scheme, or modifications were made to the ways in which the category labels were expressed, to accommodate for cases which were not suitably accounted for by the scheme in its then existing state.

This activity initially involved a brainstorming session where a wide range of episodes of individual resilience, whether experienced first-hand, observed (for example, by the thesis author in the probing study briefly described above or in other participants' own studies), or even generated on a hypothetical basis (simply to increase the number of potentially challenging or 'difficult' cases), were provided by all workshop participants and recorded onto sticky notes. The thesis author contributed a number of these captured explicitly for this purpose during the piloting and first round of a diary study on collecting resilience strategies, which is discussed at more length in the following chapter.

These example cases of resilience strategies were then grouped thematically in a collaborative exercise in which entries were read aloud, a superseding category prototype was proposed by the facilitator, and other workshop participants expressed their agreement or lack thereof. As these instances were recorded on sticky notes, the group (led by the workshop facilitators) categorised and grouped them physically across a whiteboard and adjacent wall space. Where necessary (i.e. in the case of ambiguous examples, where substantial disagreement arose), extended collaborative

discussions were undertaken whereby workshop participants and facilitators proposed alternative categories and reasoned about the applicability of the existing scheme, in some cases proposing alterations or new category prototypes. Notes were recorded during the exercise, while photographs of the resulting groupings were also taken for later reference.

Upon completion of the exercise, the workshop was concluded with a summary discussion of the day's activities, as well as potential avenues for subsequent work. During these discussions, two of the additional workshop participants volunteered further data in the form of strategy examples, observed during their own unrelated work as part of the CHI+MED project. These two further colleagues also contributed to practical follow-up work, described in 5.4 below.

5.3.2 Workshop Findings and Discussion

During the course of the workshop exercise, a total pool of 62 instances of resilience strategy use were recorded, grouped and discussed (a copy of which are available in Appendix B1). Of these, the primary thesis author contributed a total of 12, of which one was observed during the probing study described previously in Chapter 4, while 11 were observed during an initial diary study pilot round, further described below in Chapter 6.

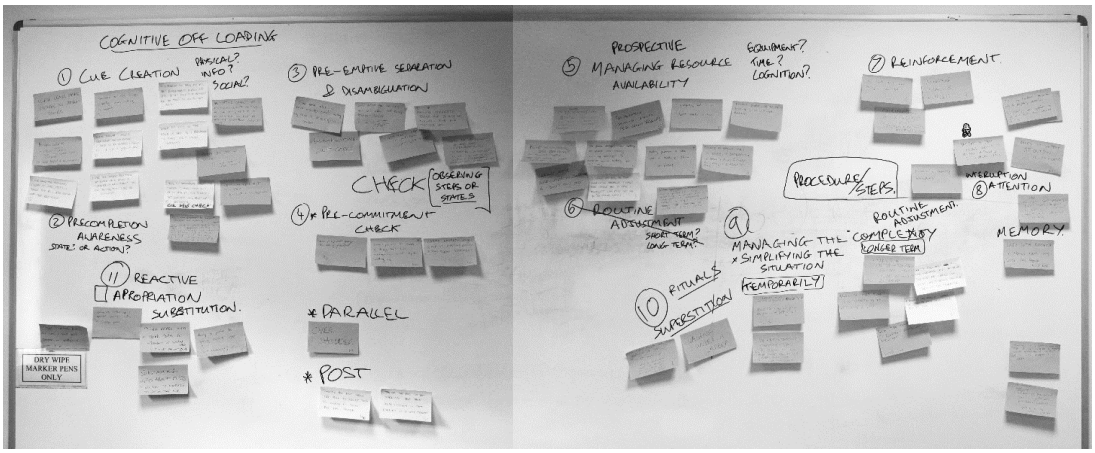


Figure 17. Composite Image of Workshop Output

In the thematic sorting exercise, led by the thesis author and undertaken collaboratively, we also noted the groupings from the workshop data largely fell into alignment with the pre-existing categories, representing 44 of the 62 cases. This left a total of 18 exceptions, which were used as the basis to form new groupings or strategy types. Of these remaining cases, the thesis author contributed a total of 5 (including 4 from the diary study described in the following chapter, and 1 from the study described in the preceding chapter). These new groupings were generated in an ad-hoc fashion during the collaborative workshop discussions and are discussed in further detail with examples in 5.4.1 below, however a brief overview of each is presented here.

Appropriation / Substitution (reactive)

Strategies which involved the appropriation of items for novel or unintended uses, or substituting one resource as another. As reflected by the reference to 'reactive', in all the cases discussed at the workshop, these strategies were enacted in a responsive/reactionary way to some kind of perceived challenge or vulnerability.

Interruption / Attention

Strategies which explicitly and primarily involved mitigating or managing interruptions or threats to attention.

Memory

Strategies which explicitly and primarily involved managing the risk of 'forgetting'.

Managing the situation / Simplifying the situation (temporarily)

Strategies which involved temporarily (in all observed/discussed cases within the workshop) altering or adapting the format of the task at hand to reduce complexity.

Rituals and Superstition

Strategies which were enacted to address a perceived superstitious threat.

Misc / Uncategorised

Strategies that fell neither into the original 7-item version of the scheme, nor the categories outlined above.

It is worth noting that these category titles are expressed in the deliberately temporary, 'placeholder' terms we generated on the day (with the exception of Misc/Uncategorised, which is a title composed here to describe a small grouping of two strategies that were separated from the existing groupings in an untitled pairing), while the brief descriptions have since been composed and added to provide clarity here.

The group (consisting of the workshop organisers) subsequently met to discuss the implications of these findings, and the more detailed analysis stemming from this is presented in the following section. Based on a cursory analysis though, it would be fair to say that while the majority of cases conformed to the original iteration of the scheme (as proposed by Furniss, Back and Blandford), this exercise demonstrated that further development was warranted, owing to nearly 30% of our cases not adequately being accounted for by the original 7-item scheme.

5.4 Forming and Validating Amendments to the Categorisation Scheme

Following on from the aforementioned workshop activity, the workshop organisers (Dominic Furniss, Jonathan Back and the thesis author) met to collaboratively analyse and discuss the output from the workshop session, and the immediate steps forward in terms of developing the categorisation scheme.

Based on our efforts to apply the existing 7-item scheme to the pool of strategies presented during the aforementioned workshop, we concluded that there were two primary ways in which the scheme required refinement. The former of these was to expand the coverage of 'breadth' of the scheme, to include concepts that

had hitherto not been accounted for in the scheme. The latter way in which the scheme was to be developed would be to improve its depth by refining the category labels and descriptors, essentially the wording of the scheme, given that even subtle nuances in the manner in which concepts were expressed, introduced some clear semantic complications.

5.4.1 Expanding Scheme Coverage

As noted, during the workshop exercise and subsequent analyses, a number of strategies were discussed that seemingly were not well represented within the original 7-item scheme. In the majority of these cases, this was not actually because they were completely unaccounted for, as many could have been assigned to one category or another. Rather, during the course of our discussions and the exercise of grouping strategies by themes, new groupings emerged that seemed a more appropriate fit, based on novel common themes and features identified.

One such example discussed in our literature review (3.4.2) was the notion of *appropriation*; how people re-appropriate resources and items in order to assist them in completing tasks. This topic, while absent from the original 7-item scheme, had been raised persistently in discussions with the original authors of the scheme and the thesis author, and had been considered a prime candidate in terms of expanding the scheme prior to the aforementioned workshop exercise. During the course of the workshop, strategies and behaviours featuring the notion of appropriation were raised a number of times, with 5 examples ultimately being grouped under the placeholder label ‘appropriation / substitution (reactive)’. These included examples such as using a smartphone camera to quickly and accurately capture information as opposed to noting it manually, and opening a parcel with a sharp pen when no scissors were available (both recorded in the diary study described in Chapter 6).

Another new category descriptor that emerged during the course of the workshop was tentatively titled ‘Managing the complexity / simplifying the situation (temporarily)’. Examples here included repositioning a sprite out of harm’s way in a

video game, and intentionally temporarily overdosing a hospital patient to concentrate on an immediate significant threat, while addressing the (less significant) effects of this overdose once the situation becomes more stable. These cases, both observed first-hand by workshop participants during their own wider work, conveyed an immediate improvisational response in terms of actions taken in situ, including an element of reorganising or rearranging the task to better deal with evolving threats, and seem to capture a resilient quality that was not clearly expressed in the original 7-item scheme.

A number of cases discussed during the workshop were grouped into another new theme that had been introduced during the session, that of 'Interruption / Attention'. These included examples such as altering the sequence of packing a bag to prioritise including an important item before it was forgotten (e.g. going downstairs to collect medication while it was the focus of one's attention, prior to returning to pack the remaining items, as noted in our diary study in Chapter 6 below) and momentarily deferring interruptions as a strategy to manage attention and working memory, as we observed and discussed previously during our initial probing study.

During the workshop organisers' meeting however, the group decided against incorporating this category label into our revised scheme after some lengthy discussions. Our reason for doing so was that this felt fundamentally like a different *type* of concept to those already expressed in the existing scheme, since it did not reflect actions undertaken by people being resilient, but rather the nature of the threats and challenges that had been faced. Moving towards grouping strategies in this way would have represented a re-framing, and increased ambiguity in assigning strategies to categories, owing to the observation that many such cases seemingly fitted other groupings equally appropriately. The two examples we cited here for example share common qualities with the type of strategy discussed previously, where both involve a reconfiguration of subtask item (these items comprising goals or actions executed during the conduct of a task or subtask). While such cases remain examples of resilience strategies, they were ultimately deemed a more

appropriate fit within the scheme item that describes ‘adjusting routines’, which ultimately became item number 8 in our revised 10-item scheme described in 5.4.3 below. This scheme item represented a stronger candidate for inclusion owing to its more consistent fit in terms of describing a resilient action, as opposed to a threat or challenge.

It is worth noting at this point that the remaining novel categories generated during the workshop exercise, *Memory* and *Rituals and Superstition* were discarded from the set of concepts taken forward for much the same reason. Both of these described the nature of the threat presented as opposed to the resultant actions taken. Moreover, each contained only one or two entries, which in the case of *Memory* could be amalgamated into our revised cueing strategy type (further discussed in the following section) and in the case of *Rituals and Superstition* were deemed to not qualify as resilience strategies proper (for reference, these were an aversion to walking under ladders, and the use of an unnecessarily oversized ‘lockbox’ to emphasise security).

As a further aside, it was however noted that the process of grouping strategies according to the nature of threat, disturbance or challenge faced was deemed to be not without some merit. While this did not conform to the format of the concepts already being used in the existing scheme, this reframing represented a seemingly very approachable way to conduct this exercise, and the group discussed how pursuing it could still perhaps yield insights. This is a subject we revisited and discuss at more length below in 5.5.

Returning to the expansion of the scheme, two strategies seemingly extended beyond both the existing 7-item scheme, and the novel groupings that were generated on the day (or rather, they were grouped into *Misc / Uncategorised*). These comprised the observation of using marker pens to make notes and annotate directly on patients prior to an operation, and the envisioned (not observed, but hypothetical) suggestion of device manufacturers using deliberately brittle materials in the construction of safety critical devices, to make it obvious when such devices had been dropped or subjected to potentially physically damaging handling or treatment.

The latter of these represents an interesting suggestion, however we would posit that it extends beyond the scope of the current discussion, since the nature of this represents a design decision rather than a strategy deployed by a user or frontline operative. This case does indeed demonstrate resilient qualities, however in the context of this discussion we might regard it in a similar way to the proposed design interventions forwarded by Nemeth and Cook (2009) and described earlier in 2.3.5, as work which results in devices with increased resilience properties. The manifestation of an individual's resilience in such a situation, framed within the current discussion on resilience strategies and behaviours, in this case would be for users to conduct a check for visible damage prior to operating the device.

Returning to the example whereby a marker pen was used to annotate important information directly onto hospital patients, we regarded this as a particularly interesting case. During the workshop discussions, an argument was made for including this as a 'cue' related strategy, owing to the nature of a visible cue clearly being used, and it addressing the type of threat that cueing strategies would address (namely, providing timely information to avert a memory slip). However, the group ultimately agreed that this particular case extended beyond the notion of a cue as described within the original 7-item scheme, owing to the fact it was not only timely in nature, but contained rich semantic information.

This particular example represents a useful illustration that there were two ways in which the material discussed during the workshop contributed to an expansion of the categorisation scheme. The former and most obvious of these, as has been outlined here, was in identifying new concepts that had not been accounted for in the existing iteration of the scheme. The second of these was in elaborating on the concepts we had already identified, and expanding their coverage or disambiguating instances where multiple concepts had perhaps been represented as singular items within the scheme. We continue our discussion of this latter aspect in the following section.

5.4.2 Refining the Terminology of the Category Descriptors

Discussions conducted both during and after the course of the workshop activity suggested that it would be a valuable exercise not only to add new items, but also to adjust the terminology used in expressing the category titles and descriptors. While some categories were conceptually fairly clear and consistent within the minds both of the workshop coordinators and participants, others appeared inherently more ambiguous and open to interpretation. Moreover, as previously noted, some categories seemingly could have benefited from expanding in terms of conceptual coverage, while others seemingly contained multiple related concepts which may benefit from disambiguating and more clearly articulating. One particularly pertinent example of the latter observation, which also picks up from the discussion towards the end of the previous chapter, is the notion of cueing.

In the original 7-item iteration of the scheme, the first item is titled 'Cue creation to support prospective memory', with the examples given being the use of a mobile phone alarm to remind of a dental appointment, or the use of a bookmark. Stemming from the aforementioned workshop activity however, discussions with the original scheme's authors served to identify a couple of potential areas for improvement and reframing in this case.

The primary contention was some ambiguity as to what constituted a cue, since the examples of cues used in the definition of the category title (as described above) carried relatively limited semantic meaning in and of themselves. This stood in apparent contrast with a number of examples of cue-type strategy cases which featured notes or instructions (i.e. rich semantic information) but with the timely nature and addressing the threats more generally associated with cueing. We therefore took the step of articulating this distinction by moving towards a scheme featuring *cues* (devoid of rich semantic information, as previously expressed) and *artefacts* (characterised by rich semantic information, be they physical or cognitive artefacts, and implemented in the fashion of a cue).

Additionally, the original category title made specific reference to 'prospective memory', indicating that these cues applied exclusively in the realm of mitigating memory slips. Analysis of some cueing strategies (collected via the diary study described in the following chapter) revealed, however, that cueing-type behaviours could be observed not only as a means to assist with memory, but also as a means to direct attention. In one such example, a fellow student described how they would generate cues with regards to incomplete citations in documents in progress, and explicitly stated this was not for fear of forgetting that adjustments needed to be made, but rather to direct attention and assist in locating such cases more quickly upon later review. Other similar examples emerged where cueing was used to increase efficiency or enhance performance, rather than address perceived frailties with memory. For this reason, the scope of this category item was broadened to reflect that such strategies may be applied to address a wider range of threats than those alone which concerned prospective memory.

Similarly to the above, two further category titles from the 7-item scheme appeared unnecessarily constrained owing to their wording; *Pre-commitment check* and *Routine adjustment*. In the former of these, the term 'pre-commitment' implies that checking as a resilience strategy only occurs prior to a challenge or disturbance. Some of the examples we collected appeared to challenge this notion, for example the case of a patient who, when unsure if they had taken a dose of medication earlier in the day, would check and count back on the blister pack of their medication to ensure it had been remembered. We considered this comprises of a checking-type resilience strategy that is employed *after* the point of disturbance. In the case of routine adjustment, the thesis author pointed out that the use of the term 'routine' implied a task that one would have conducted on a regular or repeated basis, whereas some observed strategies that would seemingly fall into this category (for example, the momentary deferral of interruptions as previously discussed) could occur in an ad-hoc fashion during any task, including unexampled or previously unencountered tasks. The wording of this item therefore was altered to reflect that these strategies might apply not only to 'routines' but instead to any 'procedure' or 'behaviour'.

5.4.3 The Resulting 10-item Scheme

Based on the aforementioned activities, and collaborative work to formally revise, add-to and reassess the original scheme, the group developed a refined second version of the scheme. This new iteration introduced additional items both as a means to expand coverage but also to assist with ambiguity in the boundaries between some of the existing scheme items.

The language in which the scheme was expressed was also refined, with a move towards shorter category labels in some cases, however with the addition of concise further descriptions to help further convey the meaning of each category label. These modifications were again motivated by our aims to both expand conceptual coverage, while also reducing ambiguity.

Owing both to the introduction of new items, and also the dividing or splitting of the 'cue-creation' item, we move from the earlier 7-items to a scheme comprising the following 10 items (note, a further iteration of this scheme, illustrated with examples, is available in 5.6, Table 5).

1) Managing resource availability

Ensuring the required people, tools, and/or task items are available.

2) Substituting a resource

Replacing a person, tool, or task item that is usually available with an alternative or spare.

3) Appropriating a resource

Innovative use of people, tools, or task items to overcome an anticipated vulnerability.

4) Creating new cues

Using place markers to support memory and attention.

5) Creating new artefacts

Making lists, notes, or drawings to help simplify or manage the task.

6) Separating task items

Disambiguating task items to avoid confusion or facilitating their findability.

7) Reinforcing an existing safety barrier

Taking additional safety precautions by adding to an existing safety barrier.

8) Adjusting a procedure or behaviour

Modifying task steps or behaviour to overcome an anticipated vulnerability.

9) Checking before or after an action

Check to ensure that required actions have been completed.

10) Pre-completion awareness

People, tools and/or task items should not be forgotten on task completion.

In summary, the most significant changes present in this iteration of the scheme were the move from 7 items up to 10 (most importantly including the introduction of appropriation as an item, and the articulation of both cues and artefacts), the amended format of the items (featuring shorter titles however with a descriptor added to each category title/label) and refinements to the terminology used to express some of the category items (intended to increase scope or conceptual coverage where appropriate, while also reducing ambiguity and assisting with comprehension for anyone seeking to apply the scheme). We would argue that these refinements contribute an enhanced iteration of the scheme, both in terms of breadth and depth, and equip us with a richer and more nuanced understanding of the different types of resilience strategy that exist.

5.4.4 Interrater Validation of the Amendments

In order to assess the comprehensiveness and general robustness of this revised scheme, as well as its potential as a means to facilitate and inform discussion, the group opted at this point to conduct another exercise in which we would apply the scheme to an expanded pool of resilience strategies. This time, the group undertook the exercise in a different format from the previous workshop, but still with a deliberate focus on some of the 'edge case' examples which had previously proved elusive and challenging, in an attempt to tease out whether our modifications had been successful in reducing ambiguity and improving coverage.

Owing to the extended discussions between Furniss, Back and the thesis author, we also felt it would be valuable at this point to bring-in assistance from additional researchers, to validate the adjustments we had made. We therefore reintroduced the revised scheme to two CHI+MED affiliated researchers who were participants in the workshop activity but who had not, up until this point, been directly involved in the subsequent adjustments to the revised scheme. We reasoned that at this point it would be beneficial to recruit previous workshop participants, owing to their inherent familiarity both with the concept of resilience strategies and the previous iteration of the scheme (the 7-item version), enabling insights to be shared in a 'before and after' fashion.

In addition to bringing in further researchers to assist with this assessment, the group also recognised the need to expand the pool of resilience strategies to be used as test cases for the validation exercise. We therefore used a set of strategies which were derived from a diary study conducted first-hand for this purpose and described in the following chapter, as well as from the Furniss, Back and Blandford (2012) *RSDiary* Twitter stream. In addition to these sources, we were also able to harness additional cases reported by the two affiliated researchers who had offered their assistance. Both of these researchers had conducted situated observations, interviews and an online survey (as part of their work addressing broader aspects of

HCI), from which additional examples of resilience strategies were encountered and extracted.

By combining strategy accounts from all of these sources, the group was faced with a rather different issue: that it would not be efficient (owing to repetitions and redundancy in the data) or indeed practicable for this exercise to utilise all of the collected strategies, which at this point numbered several hundred. Therefore, for the purposes of this assessment, four of the researchers involved, including the thesis author, each contributed 20 episodes of resilience, which were selected based upon perceived variety and value (in terms of the extent to which contributors felt their inclusion might challenge the scheme or provoke insightful discussion). The 20 items contributed by the thesis author are available in Appendix B2, and are specifically denoted by being labelled as "First" under the "Validation" column.

The group provided each researcher with the 10-point categorisation scheme, along with a set of brief descriptors to further articulate each of the categories, as presented in 5.4.3 above, and requested each researcher to independently select an appropriate category for each of the 20 episodes of resilience they had submitted. In addition, researchers were also able to annotate any particular strategies with comments if and where they deemed it necessary (for example in particularly challenging cases, or where multiple categories seemed potentially appropriate), although such comments were not obligatory.

Upon completion of this exercise and once each of the raters had independently assigned a superseding category to each of their own resilience strategy examples, the group then sought to gauge how stable these categories were by considering the level of consistency between raters on each others' selections. In order to do this, the group (led at this point by Jonathan Back, however with practical assistance and data gathering by the thesis author) conducted an informal cross-validation exercise whereby each rater was individually provided with the selections made by each of the other three raters (with each rater therefore being presented with 60 cases, so as not to reassess their own 20 selections). Raters then independently indicated their level of agreement with this data on a three-point scale,

selecting either: *Strong Agreement, Partial Agreement* or *Disagree*. In this case, partial agreement indicated general agreement however with an acknowledgement that a degree of interpretation was required, suggesting potential ambiguity. Each episode was then labelled as 'majority agreed' or 'majority disagreed' based on consistency between raters' selections, to highlight the 'edge case' episodes that had proven the most challenging to assign.

An overall majority agreement level of 79% was obtained versus 21% of cases where there was a majority disagreement (calculated based on the proportion of majority agreements or disagreements against the total number of cases). We should at this point clarify that these analyses were exploratory and informal, in order to get a sense of where weaknesses in the scheme lay, as opposed to formally assessing the reliability of the scheme.

In the interests of full disclosure, it is also important to note at this point that while the thesis author both contributed data towards this exercise, partook in it as one of the designated raters, and set up the spreadsheets upon which raters conducted the exercise, our colleague Jonathan Back took the lead on designing and conducting the analytical process. It is for this reason that the process of establishing inter-rater agreement is merely outlined here rather than presented in substantive detail. A subsequent follow-up activity that was undertaken primarily by the thesis author is presented in more detail in 5.5.

5.4.5 Discussion

Upon conducting the aforementioned cursory analysis of levels of agreement between raters' allocations during this exercise, the group noted one immediate encouraging finding was that, despite the persistence of a level of disagreement, every episode presented in the dataset we used was represented to some degree in the revised scheme. Considering this data included episodes that were not accounted for by the previous scheme (for example, verbal rehearsal to assist working memory, or behaviours facilitating the momentary deferral of interruptions observed in the lab

study outlined previously), this demonstrates an improvement in terms of coverage. In so doing, we posit that our developments to the scheme addressed what was probably the clearest limitation of the previous iteration of the scheme. Crucially, the revised scheme maintained its primary function well; to provide a useful tool for provoking and framing reflection and discussion of episodes of resilience.

We must note, however, that levels of disagreement were still observed in a number of cases, with approximately a fifth of cases resulting in significant disagreement, whereby not only was there no consensus between raters' assessments, but there was in fact no clear prevalent rating across responses. This indicated that some ambiguities persisted in terms of how the scheme could be applied, and how the category descriptors had been expressed.

Analysis of qualitative feedback regarding raters' subjective experiences of applying the scheme indicated additional clarification was particularly required in some specific cases, for example the categories *Reinforcing an existing safety barrier* and *Separating task items*. The group also determined from our analysis that these were the categories which provoked the greatest levels of disagreement. Raters also noted that the scheme could benefit from a clearer structuring to reduce the level of interpretation required in parsing examples by the natural language category descriptors.

5.5 Exploring the Restructuring of Categories Using Temporal Framing

The initial assessment demonstrated that adjustments to the categorisation scheme had resulted in positive development, principally through expansion in coverage. Based on preliminary qualitative feedback and cursory quantitative analysis however, it was clear that weaknesses in the scheme persisted in terms of the manner in which the scheme could reliably and consistently be applied across multiple raters.

Following this exercise, the group again collaboratively discussed potential avenues for further development and refinements to the category titles and

descriptors. However, in spite of much discussion to these ends, from this exercise the group was unable to identify changes to the category titles and descriptors themselves that we felt would ultimately make a positive contribution to the utility of the scheme.

The group did identify that potential amendments and alterations could be made to the language used in some cases, which may improve levels of agreement in a future validation exercise such as that which we had previously conducted. However, any proposed refinements to these ends came at the significant potential expense of compromising some of the nuanced but important conceptual distinctions between the underlying concepts.

For example, we speculate that to merge the aforementioned 'problem case' categories of *Reinforcing an existing safety barrier* and *Separating task items*, and alter the way they are described, could improve levels of agreement. However, the group felt that each of these ultimately captured a meaningful and distinct concept, and we sought not to decrease the value and insight from considering such concepts distinctly and independently, even if to do so could decrease observable levels of disagreement in assessments of the scheme. It is clear that applying some items of the scheme resulted in challenging discussions of the concepts at play, however the group felt there was at this stage still potentially great insight to be gained from such discussions, so to increase levels of agreement arbitrarily was arguably counterproductive to our goals at this point.

The group did however feel, based on qualitative feedback, that providing further structure to the scheme could be beneficial. Adopting such an approach, we reasoned, could also result in increased levels of agreement while maintaining the distinct concepts captured in the current iteration of the scheme. In other words, taking such a step could improve the applicability and utility of the scheme without oversimplifying it, and reducing some of the subtle but important complexities inherent within it.

After generating and discussing a number of potential options, the group decided to proceed with an adjustment we refer to as 'temporal framing', an idea

proposed by the thesis author. This notion relies on us to reflect upon the nature of the threat, error or disturbance which a resilience strategy has been formulated to address, and was intended to assist selection by reducing ambiguity in the choices available to raters. The group considered this to be an application of the observation, as previously discussed in 5.4.1., that considering strategies in relation to the types of threats, challenges or disturbances could potentially represent a more approachable, structured and tangible approach on the part of our raters. This hypothesis was born out of both our CHI+MED workshop exercise, and the qualitative feedback of the researchers involved in our subsequent validation exercise described in 5.4.4.

5.5.1 Introducing the Temporal Framing Step

As previously discussed in Chapter 2.3.3., Hildebrandt et al. (2008) noted that resilience strategies could be considered in relation to the point in time at which they are implemented, in respect to the threat or disturbance they address. This leads us to the notion of resilience being anticipatory (addressing a perceived threat or challenge prior to its onset) or reactive (occurring in response to onset of such a challenge or threat). This is a notion the thesis author was keen to explore, perceiving that this might potentially assist with introducing a way to frame instances of resilience and add the structure we sought, while introducing an additional and potentially insightful dimension of resilience to the scheme.

The mechanism by which this would be achieved arose from an idea initially proposed by the thesis author, which was then taken forward during discussions with Dominic Furniss and Jonathan Back. Resulting from these discussions, we opted to implement this new idea by requiring raters, as a first step (preceding their assignment of strategies to categories) to consider whether a strategy was anticipatory, responsive or whether the strategy seemed to stand irrespective of this distinction and/or this was not easily determinable. Based on this choice, we then

Anticipating	*Responding*	*Anytime/N.A.**
Managing Resource Availability	Appropriating a Resource	Managing Resource Availability
Substituting a Resource	Creating new Artefacts	Substituting a Resource
Creating new cues	Separating Task Items	Appropriating a Resource
Creating new Artefacts	Adjusting a Procedure or Behaviour	Creating new cues
Separating Task Items	Checking Before or After an Action	Creating new Artefacts
Reinforcing an Existing Safety Barrier	Misc. or Uncertain	Separating Task Items
Checking Before or After an Action		Reinforcing an Existing Safety Barrier
Pre-Completion Awareness		Adjusting a Procedure or Behaviour
Misc. or Uncertain		Checking Before or After an Action
		Misc. or Uncertain

*Not Applicable

Table 3. Categorisation Scheme Assigned to Temporal Framing

presented a reduced subset of the 10-point scheme for selection, based on the observation that some types of strategy seemingly only exist prior to (e.g. pre-completion awareness) or post (e.g. routine or behavioural adjustment) the adverse event or threat which they mitigated. The group reasoned that this could improve levels of agreement and potentially the speed and ease of applicability by eliminating superfluous or 'meaningless' options.

The manner in which the group assigned our categories to this temporal dimension is expressed in Table 3. Where items appear in multiple columns, this

indicates that we were able to identify cases where strategies under a category may be either anticipatory or responsive. It is also worth mentioning that while the table omits the category descriptors as shown above in 5.4.3 for presentational reasons here, these descriptions were still considered part of the scheme, and were available to raters during the subsequent validation exercise described in the following section.

5.5.2 Interrater Validation of the Amendments

In this second round of investigation, the group expanded the dataset further by including 40 previously unused episodes (again obtained from the large pool of strategies we had gathered from multiple sources, as described above in 5.4.3 and available in Appendix B2 labelled as "Second" under the "Validation" column) in addition to the 80 episodes previously used in the initial round (included again to enable some level of comparison between iterations). On this occasion however, rather than providing subjects with pre-allocated selections to agree or disagree with, we requested for the investigators to independently make the selections themselves, for each of the 120 episodes of resilience. In order to capture any instances not seemingly accounted for within the 10-point scheme, the group also opted to reintroduce an additional 11th category, titled 'Misc. or uncertain'.

While this exercise was more demanding for each of our raters (since they now each selected categories for 120 cases, as opposed to only the 20 they had contributed in the previous exercise), the group felt this approach would be both more conservative and more robust in determining the true consistency with which the scheme could be applied. Requiring each rater to make each selection independently and 'from-scratch' (rather than assessing predetermined selections) also constituted a more representative approach of how such a scheme would actually be implemented in further work extending beyond our own, since anyone looking to apply the scheme would not have the luxury of pre-allocated selections for their own instances of resilience.

Upon collecting each of the four raters' blind responses, the group again sought to conduct a preliminary analysis (led by the thesis author) to ascertain the extent to which the scheme could be applied reliably and consistently, and explore the implications of introducing the temporal framing step. This was again conducted by comparing raters' responses against each other. However in this case it was necessary to adopt a different approach for assessing consistency between responses, owing to the fact that it was the raters' direct categorisations that were to be compared, as opposed to their levels of agreement of pre-existing ratings, as had been undertaken in the previous exercise.

From the data that gathered during this second assessment exercise, the group focussed our analysis on the extent to which our raters were consistent in assigning each case both in terms of (i) *temporal framing*, i.e. whether the strategy had been anticipatory, reactive or undetermined, and (ii) *category selection*, or the extent to which there was alignment of the actual categories selected across raters. While we were still looking for 'agreement' in one sense, given the different format of the data collected, we were required to establish a new scheme to compartmentalise these levels of agreement for the purpose of this preliminary analysis. In order to do so, we established a four-item scheme, ranging from complete agreement down to an agreement level of low/none.

The top level of agreement, 'complete', was taken to refer to all 4 raters being in agreement, and one level below that, a 'strong' level of agreement referred to cases where 3 out of 4 raters had selected the same category. We then calculated instances with a 'moderate' level of agreement, representing cases in which there was a 2/2 split, and finally 'low/none' reflects either a 2/1/1 split in the case of temporal framing selection, or a 2/1/1 or 1/1/1/1 split in agreement between category selection. The levels of agreement reached, both in terms of the selection of temporal framing step, and category selected, are represented in Table 4.

Level of Agreement	*Temporal Framing (%)*	*Category Selection (%)*
Complete	39	21
Strong	28	35
Moderate	23	10
Low / None	10	34

Table 4. Inter-rater Agreement

Adopting our revised approach to the assessment of the categorisation scheme, one can see from the results represented in Table 4 that while there is clearly still potential for improvement, the extent to which some level of agreement existed in the selection of categories was somewhat encouraging. Taking cumulative percentages, in 90% of cases there was some level of agreement over the selection of temporal framing step, and in 66% of cases indicated agreement with regards to category selection. However, agreement levels were largely still lower than would have ideally been observed, and in particular the observation that only 56% of cases resulted in strong or absolute agreement over category selection demonstrates that there was still significant scope for improvement in terms of the stability of the category items and reliability of the scheme.

Owing to differences in the approach adopted here, and subsequently the type of data gathered, it is not possible to draw fully direct comparisons between the data obtained from the second stage of our assessment and the earlier initial stage. This meant we could not readily infer from this data alone whether the scheme was improved over the previous iteration. However, on the basis of the above, one can conclude that the reframing of the categorisation scheme into temporal groupings did not achieve the level of structure or clarity the group sought, and did not provide the anticipated level of support for applying the scheme, owing to greater than expected levels of disagreement and disparity amongst the responses our raters provided.

Upon consulting qualitative feedback, it appears that the framing scheme added a level of confusion, and presented an additional ‘hurdle’ or opportunity for

disagreement or error. As can be again seen in Table 4, some fairly high levels of disagreement in the selection of temporal framing were observed, indeed if one again calculates a cumulative percentage, 61% of instances involving temporal framing involved at least some level of disagreement, even if in the majority of these cases, it was only one rater who selected a differing framing step from the remaining raters.

5.5.3 Discussion

As noted, while we cannot definitively say whether the addition of temporal framing was detrimental to the reliability of the scheme, it did become apparent that its inclusion presented us with issues, and on balance probably introduced a level of complexity or ambiguity that outweighed the benefits of its inclusion. One assumption we had perhaps made when discussing the merits of adopting this approach was that determining the temporal framing of a strategy example would be a relatively straightforward task. However, our exercise revealed that there is indeed still inherent ambiguity here, and asking raters to determine this presents an additional challenge which can in turn provoke discrepancies and inconsistencies for subsequent category selection (i.e. in cases where different categories were presented as a result of temporal framing step selection, it was inevitable that different categories would consequently be selected). Although this was not articulated, the group had implicitly assumed that there would only be a negligible level of disagreement in responses to the temporal framing step. In actuality, and in hindsight, agreement levels of category selections always had the potential to be negatively impacted by the introduction of the framing step, since the availability of categories was determined by framing selection. This effectively resulted in a kind of fragmentation, and meant that a rater who initially selected an incorrect (or just differently interpreted) framing step had at their disposal a reduced or different selection of categories to subsequently select from.

At this point however, one must remember that the primary focus of this categorisation scheme was to assist analysis, provoke discussion and elicit insights,

rather than to provide a rigorous taxonomy of discrete or mutually exclusive categories. The concepts captured in the scheme are inherently related and some degree of overlapping, and thus ambiguity, is inevitable. When applied to an exercise which requires a degree of subjective judgement, absolute (or a level approaching absolute) agreement is thus an unrealistic and arguably unproductive pursuit. In terms of provoking reflection and stimulating discussion as to the types of resilience strategies that exist, we would assert that this exercise proved valuable in facilitating the realisation of this goal.

Reflecting back on what we learned from this second exercise, it appears that the targeted investigation of the temporal aspect of resilience, and its relationship to threat or disturbance, proved a more challenging pursuit than anticipated. At the same time, it does appear there is still much to learn regarding this dimension of resilience, and we still believe there is potential merit and value in reflecting upon it based on its persistent recurrence in workshop discussions, while conceding that this goal is perhaps not best-realised in the manner in which we attempted it during this exercise.

The implications of this unanticipated result, together with the full category scheme, descriptors and a discussion regarding the inclusion of examples to provide additional structure, are presented in the following section.

5.6 The Present Iteration of the Scheme

Based on an extended dataset, two collaborative rounds of investigative analysis and lengthy discussion, we propose an expanded and refined version of the Furniss, Back & Blandford (2012) categorisation scheme for resilience strategies.

The initial package of work described here served to expand, develop and revalidate the categories and their descriptors. Further work aimed to structure the categories and assist with application, however upon analysis the group has determined that the subsequent complexity and rigidity that this introduced adversely

affected the consistency with which the categories could be applied without yielding sufficient benefits or insight. We have together thus opted to omit this work from the categorisation scheme we propose to take forward.

The resulting 10-point categorisation scheme for individuals' resilience strategies therefore returns to the format introduced after our initial round of refinement and assessment, as presented in 5.4.3.

Category	*Example from our Data*	*Example of Application for HCI*
1) Managing resource availability *Ensuring the required people, tools, and/or task items are available.*	Ensuring work is backed up onto public folders so that in the eventuality that a staff member is taken ill, a colleague has access to their work	If low on power, smartphones might prompt the user to note down important contact details as they will be inaccessible shortly
2) Substituting a resource *Replacing a person, tool, or task item that is usually available with an alternative or spare.*	Substituting a hotel room keycard with a credit or loyalty card in order to maintain lights and power supply to the room when the keycard needs to be removed	Enabling the user a variety of security checking information (e.g. booking reference, passport number, email address, etc.) so they can retrieve their flight details online despite not recalling all information
3) Appropriating a resource *Innovative use of people, tools, or task items to overcome an anticipated vulnerability.*	Using a baby monitor to ensure a ringing phone in a remote part of the house is not missed.	Before they were intentionally supported through smartphone design people took pictures of themselves to check their appearance and used the phone's screen's light as a torch
4) Creating new cues *Using place markers to support memory and attention.*	Flagging emails which cannot be resolved immediately but which required further action	Allowing users to configure alarms based on contextual factors (e.g. location), enabling users to compose their own cues
5) Creating new artefacts *Making lists, notes, or drawings to help simplify or manage the task.*	Composing 'to-do' lists to assist prospective memory and ensure future items are not forgotten	Affording users the ability to annotate interfaces or compose their own help text or guidance for themselves and others

6) Separating task items *Disambiguating task items to avoid confusion or facilitating their findability.*	Having different drawers or containers for each type of item used during dialysis, to make it easier to retrieve items	Allowing users to highlight emails and files by colour, stars, etc. so they can be easily detected amongst the usual email and files
7) Reinforcing an existing safety barrier *Taking additional safety precautions by adding to an existing safety barrier.*	Setting up multiple, 'back up' alarms in case the primary alarm does not function	Ensuring users complete a confirmation step prior to undertaking actions that may be harmful or destructive, e.g. emptying the recycle bin
8) Adjusting a procedure or behaviour *Modifying task steps or behaviour to overcome an anticipated vulnerability.*	Packing a bag the evening before it is required to reduce the risk of items being forgotten and maximise the time available the following morning	Assisting users with interleaving or multitasking by refraining from implementing dialogues which 'steal focus', or affording users the ability to defer such interruptions
9) Checking before or after an action *Check to ensure that required actions have been completed.*	Checking pockets of clothing before putting items into the washing machine	Email clients can scan contents of an outgoing message for the word 'attached' and issue a prompt prior to sending a message without an attachment
10) Pre-completion awareness *People, tools and/or task items should not be forgotten on task completion.*	Positioning bag between legs when out at bar, to ensure it is not forgotten upon leaving	Leaving windows open and tabs on browsers open can depict unfinished tasks. These could reopen on powering off/on so these task threads are maintained

Table 5. The 10-Point Categorisation Scheme with Representative Examples

A final addition which the group did make to the scheme (without directly altering it), based on feedback received from raters during the previously described validation exercises, was to supplement the scheme with a set of representative, prototypical examples to better illustrate the categories and assist with applicability. Table 5 combines the scheme with a set of examples, selected and arranged by the thesis author from our collective source data, and also with a set of potential envisaged or hypothetical applications (generated collaboratively, with significant contribution from the thesis author) within the context of HCI, and reflects the format with which the group intends to present the scheme moving forwards.

5.7 Evaluation and Contributions for Resilience Strategies

We began this chapter picking up the 7-item scheme for categorising resilience strategies, as originally developed by Furniss, Back & Blandford (2012). As previously noted, we have been fortunate to be able to collaborate with the original authors of the scheme in developing it further, and again wish to extend thanks for their efforts and contributions to this ongoing work.

As previously discussed, the existing scheme served a useful purpose in structuring analyses of the unanticipated strategies we observed during the conduct of the initial study, presented in Chapter 4. While the collection of concepts covered by the scheme helped provide a useful foundation for understanding some of these strategies and behaviours, and contributed a useful vocabulary with which to discuss them, we felt that the scheme could stand to benefit from further development and refinement. This was a notion that had been explicitly acknowledged in the original publication of the scheme, and indeed from our own observations, potential gaps and ambiguities in the scheme were readily identifiable. The work presented in this chapter therefore sought to develop and advance the scheme, both in terms of expanding its conceptual coverage (i.e. by accounting for strategies and behaviours

not recognised in the original 7-item version) and disambiguating the items contained within.

The work undertaken to further the scheme constituted an iterative process that encompassed a workshop activity, and two rounds of collaborative development, validation and analysis. In order to inform and reinforce these activities, our group made use of a richer and more expansive dataset, which constituted a larger and broader pool of strategies sourced from a variety of studies, tasks and settings. Many of these cases were collected and contributed directly by the thesis author, both from the aforementioned practical work presented in Chapter 4, and a subsequent diary study conducted explicitly for this purpose which we discuss in the following chapter. At this point, however, we will pause to reflect on the resulting expanded scheme, and consider some of its strengths and limitations.

Turning initially to one of the positive outcomes from this unit of work, it would be fair to say that fundamentally, we (in collaboration with two of the original scheme authors) have made progress towards the initial key objective of expanding the conceptual coverage of the scheme. This has been realised both in terms of the identification of new category descriptors, as well as elaborating upon and clarifying some of the concepts already present within the original iteration. The fact that the current version of the scheme can accommodate strategy observations that were previously unaccounted for serves to illustrate this expansion and broadening. Qualitative feedback obtained during the validation exercises would also suggest that, in some cases, ambiguities have been removed in terms of the way the scheme items are expressed, making the scheme easier to interpret and apply.

We must also acknowledge, however, that not all of the alterations we described in this chapter ultimately helped to achieve this increased clarity, with the move towards temporal framing in particular potentially contributing negatively here. We qualify this assertion with the word *potentially,* owing to the absence of definitive validation to demonstrate this. This brings us onto what we recognise is an initial important limitation of the work described in this chapter; in terms of the approach adopted towards the validation of the adjustments made to the scheme.

There were two broad rounds of development and alteration made to the scheme, which were each assessed using a validation step that involved establishing inter-rater agreement and consistency. Regrettably however, the approach adopted in conducting these validation exercises varied from one round to the next, and this removed the possibility of drawing any clear 'before and after' type conclusions as to whether our subsequent modifications (i.e. the introduction of temporal framing) had improved the utility of the scheme. We can deduce from qualitative feedback that this approach seemingly increased ambiguity and did not provide the structure and clarity we sought. Were this package of work to be repeated, we would conduct this task differently. To definitively demonstrate whether subsequent alterations had improved (or otherwise) the scheme, it would be useful to frame the validation work in such a way that direct comparisons could be drawn between the different rounds of validation.

While we acknowledge this limitation in terms of how the work has been conducted, there was some practical reasoning behind the variation in approaches we adopted between our validation exercises. As discussed earlier in the chapter, the format of the initial validation exercise, whereby raters primarily expressed their levels of agreement with predetermined selections, was proposed and spearheaded by a colleague- one of the authors of the original scheme. While this approach certainly proved to be a useful exercise in terms of eliciting insightful discussions and identifying where weaknesses and discrepancies lay, we made a deliberate and reasoned decision to frame the second validation exercise differently. We felt that by asking raters to apply the scheme directly, and comparing their selections, we had adopted a more rigorous and conservative approach. It is also important to note that this second type of validation exercise would provide a more representative process in terms of how the scheme would ultimately need to be applied by other researchers, who would not begin such an undertaking with a set of existing selections. The availability of an existing selection to agree or disagree with also potentially introduces implicit but inherent bias in raters' selections, since this 'top down' approach may influence a raters interpretation of the strategy provided. By

removing the availability of existing selections, we felt that a more accurate picture of the applicability of the scheme could be obtained.

In retrospect, it may have been more prudent to conduct the initial validation exercise in more of a similar format to that of the second. However, at this point we would reiterate that the initial format was not directly within the control of the thesis author, and the nature of that task did ultimately serve us well in terms of articulating challenges and ambiguities at that stage. We were also mindful that the exercise formed part of an iterative development process, and thus was never conceptualised to constitute a formal and ultimate validation, given the target of the exercise (the scheme) was still very much a work in progress.

One further limitation we wish to discuss at this point concerns the consistency (and in some cases, brevity) of the data upon which this work has been based. As earlier noted, the pool of strategies used to inform this work stemmed from a number of sources which included the original mechanism for data collection (the #RSDiary Twitter hashtag), the probing study presented in Chapter 4, the diary study presented in the following chapter, and strategies extracted from some further external studies including situated observations and survey data. As such, there was no standardised format across these different mediums to structure each strategy account. Resulting from this, while our approach of leveraging and aggregating data from numerous sources served well in terms of obtaining a sheer quantity of data from a broad variety of tasks and settings, significant variance also existed in terms of the detail of strategy descriptions and contextual information provided.

Qualitative feedback from our raters illustrated that the scheme itself was not the sole source of ambiguity in categorising resilience strategies, some of the strategy accounts themselves also appeared inherently ambiguous, owing largely to brevity in a number of cases. For example, one strategy account simply read as follows:

> "I have post-it-notes stuck on the wall by my bedside light and also on my bathroom mirror to remind me"

Unfortunately, examples such as this necessitate a certain level of assumption and interpretation on the part of raters. What do such post-it notes include? Were they, for example, simply a set of basic reminders such as 'remember keys before leaving', or did they contain richer information, such as the login credentials to websites or other such information? While such a distinction may seem trivial, when scrutinising strategies to the level of depth intended by our scheme, this becomes a meaningful disambiguation. For our raters, such an example could merely be a cue instance, or it could describe the creation of a cognitive artefact. It is precisely facets like these which the scheme helps to identify and reason about, however this does not change the fact that some inconsistencies between raters' selections could very likely trace their roots back to ambiguities in the strategy accounts, rather than the scheme/instrument itself.

One further example of where ambiguity in strategy accounts highlights the subjective nature of raters' selections is in the following case:

> "I flag any important emails that contain links to websites and logins that I use frequently, they appear in my outlook on the front page and I use them as bookmarks"

The above strategy is ambiguous in a different way. Here, the ambiguity comes less as a result of insufficient information in the strategy account but more in terms of multiple strategies seemingly being applicable., and reflects the complexity in some our strategy accounts. This case for example could be interpreted as an instance of cueing (in utilising the email applications flag functionality, or placing windows as cues), however it also seemingly demonstrates behavioural actions to manage resources (in terms of maintaining the availability of informational resources).

Edge case examples such as the above therefore illustrate what, as reported directly by our raters, constituted a persistent challenge that remained across all rounds of their application and validation- the 'judgement call' still required in determining which category to select when more than one seems appropriate. The

extent to which multiple strategies seemingly overlap is an interesting notion, and one that merits further discussion. This is a topic we explore in much greater detail in Chapter 7, as we move towards reconceptualising the notion of what a strategy is and comprises of.

5.8. Conclusions

The work presented in this chapter constituted an insightful and useful exercise in terms of broadening and refining our understanding of what resilience strategies are, and what different types of strategy exist. In so doing, this work provides an enhanced theory base for addressing our initial research question (1.2.1), which queried what constitutes a resilience strategy, and what different types of strategy exist. In utilising a workshop exercise, the work here also advances us, to a more limited extent, towards the resolution of the third research question concerning approaches for investigation. Referring back to the contributions set out in 1.2.2, the work described here forms the core part of our second contribution in terms of delivering a revised and expanded scheme for the categorisation of resilience strategies, while also partially addressing contribution 1 (the expanding of the pool of resilience strategies for analysis, in terms of the examples gathered during the workshop exercise) and contribution 4 (in its development of the workshop and subsequent follow-up activities as a means to analyse resilience strategies and behaviours.

In developing the categorisation scheme for classifying resilience strategies, we cemented our conceptual foundation for the topic, and fine-tuned a vocabulary with which to discuss and analyse resilience strategies and concepts. Collaborating with two of the authors of the original scheme also provided a valuable opportunity to approach the topic with the benefit and insights of early, but specifically targeted work addressing the topic at hand. This helped provide a ‘head start’ in terms of adopting our approach to better understanding resilience at an individual level, and a

useful grounding particularly in some of the more nuanced and challenging facets of the topic, as well as approaches for the analysis of resilience strategies.

It should be stressed that while we conclude this package of work with an improved understanding of resilience strategies, we still do not yet possess a fully-formed account regarding some of the intricacies of specific strategy types. The artefact we have generated, in the form of the revised 10-pont scheme, is a demonstrably improved iteration of the pre-existing initial version. However, at no point did we arrive at a scheme which would be applied with the level of consistency and reliability that would be expected of a formal taxonomy.

While perhaps an ideal outcome may have been to arrive at a set of categories that could account for all observable resilience strategies with absolute accuracy and consistency across raters, we recognised early on that such an outcome would always be an unrealistic pursuit. The application of such a scheme is an exercise that will always require subjective judgement, and in any such undertaking, a certain level of variance is to be expected. The very nature of resilience strategies themselves also presents challenges, since we are ultimately considering here a range of behaviours that by their definition are often ad-hoc, improvised and not formalised. To construct a scheme that can consider such a broad variety of behavioural phenomena and divide these neatly into a set of rigid, discrete categories, would be no mean feat.

Another challenge that we were faced with, as discussed, was some ambiguity in terms of the way strategies were expressed and described. Practical constraints dictated that many strategy accounts were brief, and this lack of detailed or contextual information resulted in challenges in interpretation. During the course of this work however, we moved towards a structured mechanism for the collection of data, utilising a traditional diary study format. This practical work, some of which was conducted concurrently with the conceptual and theory-building presented in this chapter, is presented in Chapter 6.

Chapter 6: Study II: A Diary Study for the Collection of Everyday Resilience Strategies

6.1 Chapter Introduction

An implication of our initial probing study (Chapter 4) was that it revealed limitations in our understanding of the breadth and variety of different types of resilience strategy. While the previous chapter presents empirically-informed conceptual work which we undertook to yield insights in this area, as discussed in 6.2.1 below, we required an expanded pool of strategy examples, which constitute the 'data' upon which to base our theory-building work. The work described in this chapter represents practical work undertaken to deliver this increased pool of strategies, thus expanding our repertoire of real-world strategy cases. We note here that as with the work described in the previous chapter, this unit of work was an iterative collection of activities, that were conducted in parallel with the theory-building work previously described.

This chapter introduces the notion of a diary for capturing resilience strategies, and discusses our motivations in adopting this approach. We go on to describe how we conducted a two-round diary study, which served both to inform developments and revisions in the categorisation scheme, and also later to provide further material with which to assess these resulting alterations and refinements. We later revisit some of the conceptual insights gained during the course of the previous chapter, and discuss how the work described here has served to inform and advance our understanding of what strategies exist, and reveal complexities and challenges that persist in our work to classify and categorise strategy instances. The chapter closes with an evaluative discussion, reflecting on the approach undertaken, and also considers potential new approaches and avenues for expanding this work in the future.

6.2 Study Background and Introduction

We would like to begin by reemphasising at this point that the practical work presented here in Chapter 6 was conducted concurrently with the conceptual work previously discussed in Chapter 5 above. We therefore will make frequent reference back to the aforementioned work when describing both the motivations and rationale for this work, and the subsequent findings and conclusions we drew. While we recognise this is an unconventional format for reporting such work, we feel that this represents the most logical way to present what was a significant and iterative, recursive package of work. The alternative would have been to present a fragmented discussion, alternating numerous times between smaller units of practical and theory-building work, which we felt is not well suited to a thesis format.

In opening this chapter, we also recognise that the use of a diary study to collect occurrences of resilience strategy use represents a departure from the controlled study approach we previously adopted in our last unit of practical work as described in Chapter 4. We therefore begin our account of this work with an explanation of the rationale behind this decision, and the benefits we see in adopting two very different, but complimentary, approaches.

6.2.1 Previous Work and Rationale for the Diary Study Approach

As introduced previously, Furniss, Back and Blandford (2012) presented some of the first work to explicitly and exclusively investigate the concept of resilience strategies within the context of HCI. In this work, the authors introduced the concept of a 'diary' of sorts, in the form of a collection of personal experiences on twitter, for the collection of resilience strategies. Until this point, previous work on gathering resilience strategies had largely taken the form of researchers observing the implementation of strategies first-hand, either in controlled laboratory studies (e.g. Back et al., 2008), or more commonly through obtaining strategy accounts from situated 'real world' interactions via interviews and task/workplace observations (e.g. Hildebrandt et al., 2008; Furniss et al., 2010). Much of this work also did not

target resilience primarily or specifically, rather addresses it as part of broader studies investigating working practice within specialised contexts (for example in healthcare, or safety-critical control rooms).

While the collection of strategies by means of observation or from interviews and task/workplace analyses constitutes a clear and valuable means by which to elicit strategies, this is a relatively resource-intensive approach to gathering data. By their nature, resilience strategies fall outside of the envisioned scope of an interaction and thus are not sufficiently commonplace to be reliably observable in great frequency in closely constrained environments. A consequence of adopting observation as a means to capture strategies is therefore that while rich contextual data may be available, one must conduct this work with great frequency in order to yield a sufficient volume of strategy occurrences upon which to build a usable corpus of data. A further limitation of utilising solely this method is that such approaches are inherently likely to be confined to tightly scoped tasks and settings, meaning that such insights are often task-specific and encapsulated within their respective workplaces and situations. Such an implication introduces challenges when one seeks to establish an analytical apparatus that applies beyond these targeted and specialised contexts. To conduct multiple situated observational studies across a sufficiently broad variety of tasks and settings would ultimately be unfeasible, given the practical constraints of this PhD.

Furniss et al. (2012) noted, however, that the approach of adopting a diary study had previously been deployed successfully within the body of work investigating error, and thus proposed that the approach may be suitable for collecting resilience strategies. From the widespread use of adopting such methods in broader social sciences work, one recognised advantage of utilising diary studies is the potential for them to yield a more substantial body of data, since the collection of episodes and accounts can be ‘outsourced’ to numerous frontline actors, as opposed to requiring the costly direct and first-hand intervention of a (typically much) smaller number of researchers. There is also an increased scope to open diary studies up beyond specific tasks and settings, which form the focus of situated observations.

Rather than adopting a traditional, paper-based diary format however, Furniss et al. (2012) implemented their diary study using a #RSDiary 'hashtag' on the popular social network *Twitter*. This experimental method introduced some notable advantages, in particular the ability to open the exercise up to a potentially vast number of contributors irrespective of their geographic location, and conveniently also irrespective of task or setting. This is something the authors capitalised on by framing their work as looking at 'everyday' resilience strategies (i.e. not confined to a specific domain, task or setting). As an added bonus, the approach of using Twitter also carried practical advantages in terms of data handling, for example bypassing the need for manual transcription, and resulting in the availability of a centralised pool of strategy accounts with relative ease.

The approach adopted by Furniss et al. did, however, also introduce a number of challenges and limitations. For example, the use of Twitter as a tool for data collection restricted entries to being no more than 140 characters in length (the maximum length of a tweet at the time of undertaking), which necessitated brevity. Such a limitation would, inevitably in some cases at least, lead to entries lacking in detail and depth, including potentially valuable contextual information. The method also introduced a reduction of control, when compared to a traditional diary study, in terms of how the exercise was framed, how participants could be instructed or guided, and the ability to follow-up or elicit further detail and information if and when that might be deemed useful or necessary.

Further to this, another issue which the authors identified in their study was that while the *potential* number of contributors was vast, actual engagement and contributions did not reflect this. The authors themselves accepted that their sample size was very limited, with some 5 unique contributors to the data, however 83% of entries were recorded by only one member of the sample (the first author of their publication). Given that the sample also consisted exclusively of academic researchers, there are naturally questions regarding sample variety as well as size. This was mitigated, to an extent, by the fact that many of the strategies recorded were observations of the resilience strategies of others, however the sample in terms

of direct contributors was still limited and observed strategies on the part of others were still recorded through the 'lens' of a researcher rather than directly by those utilising the strategies. It should be recognised, however, that the exercise was reported as early work and treated as a proof of concept by the authors, rather than an exhaustive or substantial data gathering exercise.

Despite these limitations and with these caveats in mind, Furniss et al. still achieved their intended goal of obtaining a pool of occurrences of resilience strategy use, from which they composed the initial 7-item scheme as discussed in Chapter 5. In so doing, Furniss et al. served to demonstrate the potential merits of adopting a diary study approach, and how such an undertaking may contribute to the study of resilience strategies.

Returning to our position with regards to the work in this thesis and our motivation for conducting the diary study described here, there are several things to note, and potential improvements to draw, from the initial Furniss et al. #RSDiary concept. As stated earlier in the opening of Chapter 5, our primary aim for this package of work was to develop the categorisation scheme from its relative infancy into an analytical apparatus that could better be used to structure analyses of resilience strategy accounts, transcending specific tasks or domains. In addition to advancing this conceptual contribution however, we also required a richer (in terms of both depth and breadth) and expanded (more numerous, and updated) pool of strategies, since such real-world strategy accounts represent the 'raw data' of work into better understanding the nature of resilience strategies. Leveraging the strategies collected via the #RSDiary exercise had been instrumental in work thus far, but owing to the aforementioned limitations in the initial Furniss et al. twitter-based approach, we felt that such work required a supplementary and further developed methodological approach for the collection of resilience strategies. It is this need which we sought to address in the work presented within this chapter.

6.2.2 Study Introduction and Aims

As framed above, our initial probing study revealed potential gaps in understanding in terms of the different types of resilience strategies that exist. While we moved towards exploring this topic and attempting to address these gaps by developing existing work in this area, we also required a further source of strategy examples or instances of resilience from which to build this work. The availability of a rich and varied pool of instances represents an important step in our study of resilience, supporting and informing the broader thesis goals of better understanding and reasoning about resilience at an individual level.

Our second study, discussed here, sought to replicate and expand on the work previously described by Furniss, Back & Blandford (2012) through the collection and analysis of self-reported episodes of individual resilience collected via a diary study. Addressing the fundamental question concerning what 'types' of resilience exist at an individual level, the general idea here was not to focus attention on a select subset of resilience (as had been the intention with our initial study) but to move in the other direction: to cast as broad a net as possible in establishing a wide-ranging repertoire of resilient strategies for subsequent analysis. The primary early intention was to determine if any further resilience-type behaviours and strategies could be identified which were not previously accounted for in the literature. In order to do so, we sought to establish a study that would be broad in scope, in terms of collecting a variety of strategies, while paying particularly close attention to 'edge-case' or unusual strategies which pushed the boundaries of what might constitute a strategy, and the different types of strategy Furniss et al. had encountered and articulated. This also provided us with the opportunity to gather data which could uniquely be obtained in a self-report format: individuals' own subjective accounts of the motivations, perceived effectiveness, underpinning mechanisms and other attributes of the strategies which they were reporting. In so doing, we aimed to achieve an expansion of the data previously collected in existing studies, both in terms of the work of Furniss et al., and our own initial probing study.

It was therefore decided we would build upon Furniss et al.'s work by both enhancing our method and expanding our sample, to generate a greater frequency as well as more diverse variety of entries. While the use of Twitter did have its practical advantages, we reasoned that replicating this investigation in the form of a more traditional, paper-based diary study format could deliver three notable advances:

- Scope for longer and more detailed entries, owing to the removal of the 140-character limitation necessitated by the use of Twitter
- A larger and more diverse sample was recruited, thus potentially providing a broader spread of entries
- The ability to probe subjects- both with prompts prior to composing entries, as well as retrospectively for clarification and elaboration, to assist us in obtaining richer contextual information for each strategy where required

Methodologically, this approach also extended us the opportunity to conduct first-hand practice on how to elucidate strategies from a non-expert sample and find out whether such an activity could prove successful. Further, it was hypothesised that using this method in addition to the experimental approach adopted previously could provide us with not only practical experience, but also data of wider remit, owing to the combination of mixed methods. Self-report data would intrinsically have differing qualities and could contribute a new 'richness' when considered in addition to the observational data captured in our initial probing study.

The strategy instances gathered here were used to inform the development and refinement of the categorisation scheme originally developed by Furniss et al. and discussed in more depth in the previous Chapter. In our presentation of this work, we draw a distinction between two rounds of data-gathering; an initial round in which the design and diary format was piloted (which proved to be sufficiently successful to yield usable data to inform our scheme modifications), and a follow up 'full-run' which provided instances that served to verify and assess the modifications made to our scheme, as discussed in 5.4.

6.3 First Round of Diary Study

As discussed above in 6.2.2, while our study here sought to replicate the approach of using self-report measures as a means to obtain reports of resilience strategies, we sought to undertake a more conventional paper-based diary format to address the limitations noted from Furniss et al.'s online twitter-based approach.

We reasoned that by adopting this novel method within the context of resilience strategies, it would be prudent to first conduct a limited exercise to verify the suitability of the method and potentially tune and adjust the instructions and instrument (the diary itself) that would be provided to participants. While the exercise described here was consequently initially conducted as a pilot, we obtained data of sufficient quality that we were ultimately able to harness the strategy instances gathered here in our development of the categorisation scheme, as described in the previous chapter. We therefore present this unit of work as the first round of data gathering in a two-round diary study.

6.3.1 Participants

This exercise was conducted with 6 subjects and consisted of an opportunity sample, with recruitment taking the form of participants being approached by the thesis author for the purposes of the pilot. While this represents a relatively limited sample in terms of size, this was deemed appropriate given the purpose of this exercise was still to conduct a pilot and assess the viability of the approach in preparation for a more extended follow-up diary study.

The sample consisted both of research students working within the area of HCI, as well as a more general population of individuals not associated with research. By recruiting a more varied sample (i.e. not exclusively comprised of researchers, as was the case with the Furniss et al. twitter diary study) it was intended that we would have the potential to capture a more varied range of strategies, from a broader range of tasks and settings.

In a step which replicated the approach previously adopted by Furniss et al., the sample also included the primary investigator (here, the thesis author). The reasoning behind this was two-fold;

(i) To add 'autoethnographic' accounts of resilience, an approach demonstrated by colleagues as being useful in capturing vignettes of real-world behaviours (O'Kane, Rogers and Blandford, 2014)
(ii) To better understand the experience of undertaking the exercise from participants' perspective, and to assess the suitability of the instrument (both the diaries, and the prompts used to elicit further information)

While it may be unusual for an investigator to also assume the role of participant, in this particular case and given the purpose of the exercise (to capture as broad a range of strategies and behaviours as possible, and not to investigate prevalence or draw comparisons between participants), it should be noted that issues such as bias or a performance advantage were not relevant here.

To further maximise the breadth of strategies captured, it was also decided that we would not recruit any of the sample that had previously contributed to the Furniss et al. (2012) pool of strategies, owing to the potential that this may lead to repeated accounts and existing preconceptions and interpretations of what may or may not constitute resilience strategies.

6.3.2 Materials and Apparatus

For the purposes of this exercise, participants were provided only with an *information and instruction sheet* (described below and available in Appendix C), a *ballpoint pen*, and a *paper diary*. In addition to these materials, participants were also supplied with a *list of 'prompts'* to assist in reflecting upon the nature of

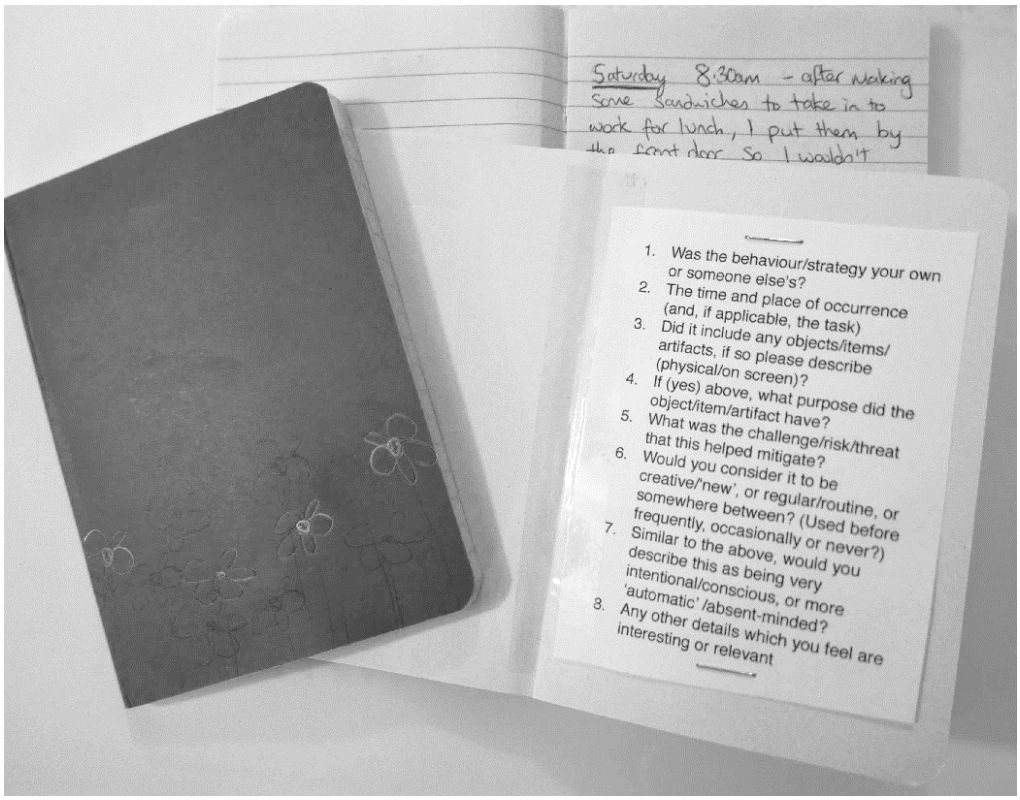


Figure 18. Diaries Used in Pilot Investigation

recorded strategies, and guide potentially relevant details to include. This list of prompts was included both in the instruction sheet, and also attached to the inside of the diaries for convenience. We discuss these prompts further in 6.3.3 below where we outline the study design.

With regards to the physical format of the diary, to facilitate the ability for participants to be able to compose entries at their convenience, we ensured the paper diaries that we supplied were suitably small to be carried with relative ease. The diaries distributed to participants in this initial run were approximately 13cm x 9cm and soft-backed (i.e. to some extent physically flexible), meaning they were easily able to fit in most pockets, and did not constitute a physical burden to participants in terms of size or weight.

6.3.3 Study Design

As noted, at this point, the exercise was conducted as a pilot investigation to assess the viability of using a paper-based diary approach to collect resilience strategies. Upon opting to utilise this more traditional diary study format, an initial consideration was in determining the nature of composing entries in terms of the level of structure to utilise. After considering the suitability of the alternatives, we opted to implement a *semi-structured* approach (Blandford, 2013), and allow subjects the flexibility to compose entries at their convenience, as opposed to at predesignated times or intervals. We reasoned that given the potential relative infrequency of encountering resilience strategies, it made more sense for our subjects to be able to record instances as and when they happened (assuming this was practicable) rather than the alternative of requiring participants to record entries retrospectively, for example every evening, which might introduce challenges in terms of accurately recollecting strategy details or relevant contextual information.

We did recognise that this approach of recording strategies as and when they arose may however not be feasible in some circumstances, particularly in cases where it would not be suitable or practical for participants to have their diary on them, or if strategy cases presented when our participants were otherwise engaged. For this reason, our semi-structured approach allowed participants to compose entries retrospectively if necessary. We did however suggest to participants that recalling strategies retrospectively might introduce difficulty in remembering them, or recalling specific details, and therefore indicated that we had a preference for concurrent rather than retrospective participation where possible.

Our approach in designing the diary study to be semi-structured extended not only to *when* participants composed entries, but also with regards to the *frequency and contents* of entries. Regarding frequency, given that resilience strategies are generally not encountered at regular intervals and can be infrequent, we felt it would not be advisable to suggest any ‘quota’, or introduce a requirement regarding the frequency of entries. Considering that this task was a pilot exercise at this stage, we

were also interested in levels of engagement and frequency if participants were left to their own decisions in terms of the number of strategies they recorded.

With regards to the contents of entries, as described in 6.2.2 above, we recognised at an early stage that one advantage of moving to a more conventional paper-based diary would be the potential for us to introduce probes to guide and structure entries. However, we did not wish to rigidly specify what participants were to include, as we felt that to impose such constraints could potentially discourage entries and reduce the scope of what participants may otherwise deem to be useful points for inclusion in an undesirable manner. We therefore adopted the approach of creating a number of 'prompts' with probing questions that we asked participants to consult prior to completing each entry. Reflecting on what we perceived might yield valuable information or introduce new insights, we arrived at the following prompts (described in italics under each prompt):

1. Was the behaviour/strategy your own or someone else's?
   To indicate whether the strategy was deployed by the participant, or by someone else. This was asked to determine the extent to which our participants actively engaged in strategy creation

2. The time and place of occurrence (and, if applicable, the task)
   When and where the strategy was observed or encountered. This could provide contextual insight into the general circumstances in which the strategy occurred

3. Did it include any objects/items/artefacts, if so please describe (physical/on screen)?
   Whether the strategy involved any physical or digital items. This could again represent useful contextual information, and encourage participants to elaborate on any items that were used

4. If (yes) above, what purpose did the object/item/artefact have?
   What function the item served. This was asked to gain a deeper understanding of how strategies involving items may have worked

5. What was the challenge/risk/threat that this helped mitigate?
   This encouraged participants to reflect on what would have happened in the absence of the strategy, and was asked to help explain why a strategy may have been used

6. Would you consider it to be creative/'new', or regular/routine, or somewhere between? (Used before frequently, occasionally or never?)
   Whether the strategy was novel, or frequently repeated. This was asked to help us understand the nature of the strategy in terms of it being 'ad-hoc' in nature, or routinely deployed/possibly embedded in the task or setting

7. Similar to the above, would you describe this as being very intentional/conscious, or more 'automatic' /absent-minded?
   Whether the strategy seemed to be the result of conscious and deliberate behaviour, or was more of an absent-minded intervention. This was asked as we had an interest in the 'intentionality' of resilience, in terms of exploring strategies versus behaviours

8. Any other details which you feel are interesting or relevant
   An opportunity to provide further contextual information. This was asked simply to capture any detail that the participant may consider relevant, but which was not captured in the previous prompts or instructions

While we encouraged participants to consult this list of prompts prior to and during their composing of strategy accounts, we did not explicitly suggest participants address each point in turn. The intention by introducing these

prompts was not to 'tell participants what to write', rather to provoke reflection and guide participants in terms of what we considered to be pertinent and valuable points to consider.

With regards to the length of entries, we hoped that the introduction of the prompts would indirectly encourage entries with sufficient length and substance to enable the analysis required as part of our efforts to develop the categorisation scheme. However, given the nature of this as a piloting exercise at this stage, we also felt that imposing requirements for the detail of length of entries may be counterproductive. This addressed a perceived trade-off in terms of requiring extensive detail, which may have introduced the undesirable effect of deterring subjects from composing entries (particularly in cases where subjects were in a rush or unsure whether their entry was sufficiently interesting or useful to be recorded) versus the previously adopted approach of limiting strategies to brief accounts (which restricted the ability for subjects to record richer and potentially useful contextual information).

6.3.4 Task Procedure

In order to provide consistent and standardised direction to participants, we drafted an information and instruction sheet to supply to participants prior to commencing the diary exercise. This instruction sheet, in summary, provided the following information:

- A layman's introduction to the topic of resilience, and a description of what resilience strategies are
- A set of examples of resilience strategies, which were composed to represent each of the different types of strategy (as described in Furniss et al., 2012) to encourage breadth of responses
- A brief outline of the purpose of the study (i.e. to collect a range of everyday resilience strategies, to better understand the topic)

- How strategies should be recorded (i.e. in the paper diaries provided, or additionally as a secondary measure, via a purpose-generated email address if considered more convenient at the time a strategy was recorded)
- When strategies should be recorded (preferably at the time they were encountered, however if this was not practical at the time, retrospectively from memory)
- How many strategies should be recorded (as many as possible, but with the consideration that this number would vary day by day, and the reassurance that there was "no such thing as too many or too few")
- Guidance on what/how much to write (participants were told this was a 'free-form' diary study so were not explicitly told what should or should not be written, or given limits as to the length of entries)
- The list of 8 prompts or probing questions, as described above in 6.3.3 (to encourage more detail and contextual information)
- Two more detailed examples of how strategies may be presented (these comprised short paragraphs and were intended to encourage entries that would be of a sufficient length to provide sufficient material for meaningful understanding and analysis)
- What to do if participants were unsure whether something fitted the definition of a resilience strategy (participants were encouraged to record these cases)
- The duration of the study (5 days)

With regards to the procedure of conducting the study, the investigator briefly outlined the study and provided the instruction sheet and a consent form, which participants were requested to read through at the time so any questions could be answered. Participants were then supplied with the remaining materials (the diary itself, and a ballpoint pen) and were instructed to begin the exercise, for a duration of 5 days. This duration was chosen as we anticipated it would provide enough time for

participants to utilise or encounter at least one or two strategies, whilst still remaining suitably short given that the exercise was conducted as a pilot study.

Upon completion of the activity, the investigator met each participant to collect the diaries and also to ask about the experience of undertaking the study, in order to gather feedback regarding how the instructions and format of the study could be improved for the later full conduct of the study.

6.3.5 Data Analysis Approach

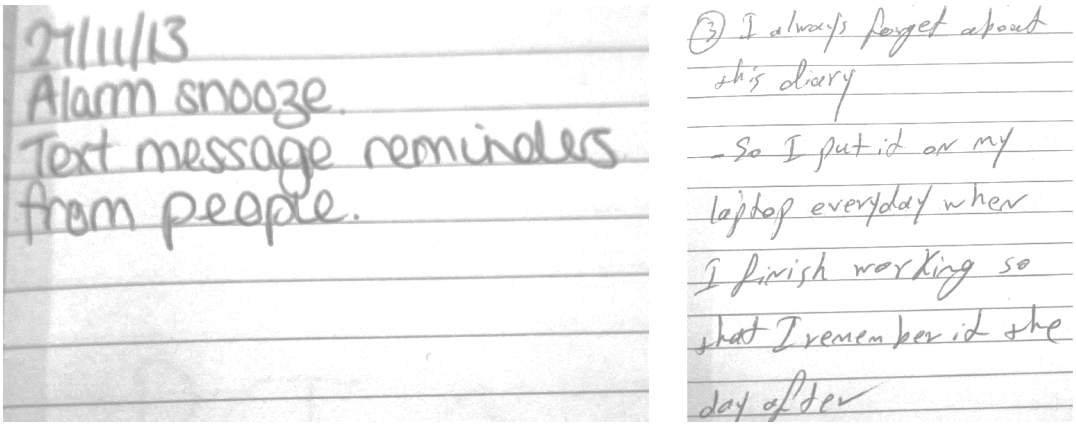
As outlined in the opening of this unit of work in 6.3, while this activity was originally undertaken as a means only to pilot the implementation of our diary study, given the success of the activity and the fact it provided a number of interesting and potentially insightful strategy accounts, we opted to make use of some of this data. This took the form of selecting a subset of the most interesting and appropriate cases, and contributing these to the workshop activity described in the previous chapter (5.3). The use of the strategy accounts we gathered necessitated an approach for the analysis of this data, which we outline here.

As the data collected here was to be used in the collaborative workshop session previously described, it was necessary to assess the collected strategies, and reduce these down to a selection which we could take forward to the workshop. This decision to use only a selection was made based on the purpose of the workshop, which was to consider ‘edge case’ strategies that challenged the existing Furniss et al. 7-item categorisation scheme, and use these to expand and refine the scheme. It would, therefore, have been less insightful or productive to take forward strategy accounts that were relatively simple and straightforward in nature (i.e. ‘easy fit’ examples) at the expense of including more challenging edge cases that would better elicit routes to broadening or refining the scheme. We also reasoned that by distilling the data from this diary exercise and using only the most appropriate cases, we could combine our edge case examples with a selection of similarly appropriate strategies collected by our colleagues using other approaches as described in 5.3.

Upon collecting the diaries, each strategy was transcribed and an initial assessment was made by the thesis author with regards to the appropriateness and utility of the data. This involved individually considering each case, as is described by Braun and Clarke (2006) as their first of the six stages of *thematic analysis,* an approach we leveraged aspects of in assessing and analysing our data. Each strategy account was considered in particular with regards to three criteria;

- whether the item did or did not potentially constitute resilience
- whether sufficient depth and detail had been included
- whether the item represented an 'edge case' in the context of the 7-item Furniss et al. categorisation scheme, or seemingly contributed a concept not captured within the scheme

While the extent to which each strategy case conformed to or violated these criteria was a subjective judgement, a conservative stance was adopted in excluding strategies owing to the above. Only a very limited number of cases were deemed to clearly not constitute resilience (considered as not containing any discernible resilience-related qualities as articulated from our literature review) or to contain insufficient detail (whereby necessary information to ascertain the purpose or method of a strategy was not present). When considered within the context of Furniss et al.'s 7-item categorisation scheme however, most cases could seemingly be categorised with relative ease. We therefore noted the limited number of strategies that seemed either to not be represented in the scheme (i.e. appeared resilient but not in terms of any of the 7 concept groupings noted in the scheme), or which challenged the phrasing of a category (e.g. appeared an appropriate fit within a category, but challenged the boundaries of description of that category). Figure 19, shows examples of where items were (i) not considered to represent a resilience strategy, or considered to not contain sufficient depth (*"Alarm snooze. Text message reminders from people"*), and (ii) were straightforward to apply to the original scheme (*"I always forget about this diary – so I put it on my laptop*



(i) (ii)

Figure 19. Examples of Excluded Diary Entries

everyday when I finish working so that I remember it the day after" - in this case, the strategy included constitutes a clear example of cueing to support prospective memory).

In order to improve the flow of the workshop activity and facilitate the discussion and decision making, we deemed it necessary to summarise some of the longer diary instances. This would assist workshop participants in quickly interpreting and extracting the essence of a strategy from what otherwise would have been longer passages of text (which were also not well suited to the 'post-it note' format we ultimately used). This involved distilling entries into shorter text while retaining the essence or key concepts contained within the strategies. While not comprising a formal 'generating of codes' as described by Braun and Clarke in their second stage of thematic analysis (which represents *decomposition* into codes representing key components, as opposed to our *distilling* to summarise the core concept in a summary manner), this represented a step that was somewhat conceptually akin to coding in its identification of the core underlying values contained within our data. An example of this is that in one of the longer entries we used, a participant described an improvised regime of taking a photo of a calendar in the real world to create a digital copy, compensating for unreliable calendar

synchronisation across multiple digital devices. For the purpose of the workshop exercise, this was composed on the post-it note as “Taking a photo to quickly and accurately capture information”. While in such cases only a minimal summary of the strategy was taken forwards, the context to these diary entries was described verbally when introducing each strategy to supplement these summarised versions, and the original diary entries were available to be consulted should further elaboration or clarification be necessary.

Braun and Clarke describe the third stage of thematic analysis as “Searching for themes”. Given that the exercise described here was being used to assess a set of themes already articulated by Furniss et al. however, we were in the unusual position at this stage of already having a list of themes to consult. At this early stage of the work therefore (i.e. selecting instances to take forward to the workshop), the exercise we conducted represented a deductive (or “theoretical”, as referred to by Braun and Clarke) approach by assessing our strategies against the existing 7-item scheme. We did subsequently however use the workshop discussions to frame our development of the scheme, which involved the inductive activity of deriving new themes from this data, in a process discussed in 5.4 and referred back to later in the Chapter.

The latter stages of thematic analysis as described by Braun and Clarke concern the reviewing, defining and naming of themes. These activities were not conducted by the thesis author during the initial analysis of our pilot data. We did however conduct work analogous to these stages in collaborative activities, both during the workshop and in our subsequent discussions and theory-building work with Furniss and Back. These activities, outlined in Chapter 5, are revisited in 6.4 below as they leveraged an expanded pool of strategies containing diary entries captured during the second phase of our diary study.

6.3.6 Results of First Round

While envisaged as a pilot activity, the study described here ultimately ended up serving two distinct purposes. On the one hand, as had been intended, the study assessed the feasibility of using a traditional paper-based diary approach to collect instances of resilience strategy use, including the suitability of the diary-format and instructions we had generated for the purpose. Additionally however, as indicated previously, we also opted to utilise some of the resilience strategies we captured from the diary entries in our efforts to enhance our theory base, by selecting a subset of suitable cases and closely considering them in a workshop activity.

As a result of this 'dual purpose' nature of the study, we present our results section here in two parts, whereby the former considers the findings in terms of assessing the undertaking as a pilot exercise, while the latter describes the cases taken forward and used to inform our workshop into developing and refining the categorisation scheme for resilience strategies. It is worth reiterating at this point that beyond the limited cases selected specifically for workshop inclusion, the remainder of the data from this first round of the diary study was combined with data from our second round of the diary study, forming a final composite dataset which is available in Appendix D.

6.3.6.1 Pilot Study Findings

Across all participants and over the 5-day duration of the exercise, a total of 66 resilience strategy instances (excluding identified non-resilience items) were recorded. The full list of these entries is recorded as part of our composite dataset in Appendix D, with the term "First round" in the remarks column denoting strategies collected in this pilot or first-round of the data collection.

This served to demonstrate that the use of this diary study approach was indeed a viable way of gathering a relatively large number of resilience strategies even within a limited timeframe, especially when considered in the context of the

previous and comparable Furniss et al. data gathering exercise on twitter, which captured 49 strategies in total.

We did however encounter notable variation across the collected strategies, both in terms of the frequency of instances recorded per participant (ranging from 3 up to 16), as well as the length of entries. We note, as was verified in qualitative feedback following the activity, that engagement with the list of 8 prompts (described in 6.3.3) also varied considerably.

The qualitative feedback participants provided also served to raise several issues, primarily being practical in nature. These included the 'trade-off' in practical difficulties between participants being required to either carry the diary with them (with three participants noting diaries being forgotten, and in one case, a mild stigma of being seen to write into a small diary at their workplace), or the need to later recall strategies retrospectively (difficulties in recalling strategies that had been deferred to be recorded retrospectively, on in recalling detail regarding such strategies). Additionally, in one case, the physical format of the diary was discussed and the participant remarked that they found the diary too small and too flexible (in terms of it being soft-backed as opposed to hard-backed) for comfort. Finally, in two cases of relatively low engagement, participants remarked this was due to the lack of incentive or reimbursement for participation (this was, however, an intentional decision based upon this initial run being implemented as a pilot exercise).

One further point of feedback, noted in two cases, was that concerns were raised by participants over whether they had interpreted the list of prompts correctly. While we reassured the participants that there was no 'incorrect' way to apply these prompts since they were merely points for consideration and to elicit more detail, we accepted that more guidance may have been appropriate to better convey the meaning of some of the prompts. This was a notion we made sure to consider when running the subsequent full data collection exercise discussed in 6.4 below.

One other useful outcome of the pilot was that by the end of the five-day period, most subjects had not reached saturation in terms of the data they could

provide, and were still recording strategies on the closing day, so a final finding of the pilot was that a study period of longer than five days would be beneficial.

6.3.6.2 Data Used in the Workshop

As noted, variation existed across entries, both in terms of the length and detail of entries but also regarding extent to which they constituted edge-cases or new concepts in the context of Furniss et al.'s 7-item categorisation scheme. Despite this, we did however note that several entries seemingly represented potentially insightful or novel strategies that could be appropriate to contribute to our efforts to develop the categorisation scheme. We ultimately took forward 11 such cases, adopting the approach outlined in 6.3.5 for their selection, and present each here along with a brief rationale for its inclusion.

(i) *I always write a piece of paper, put it on my desk, to remind me to do the 'proper citation' for my MPhil write-up… I don't think I do this because I forget to do so, but because I somehow try to force myself doing so*

This item was selected because while it represents a cue, this cue is seemingly not related to prospective memory and the risk of forgetting, but rather it is used to direct attention and support findability at a later point in time.

(ii) *Home- I store photos in folders with names containing dates as YYYY-MM-DD - this means sorting by name orders the folders chronologically*

This item seemingly incorporated aspects of multiple categories ("separation and disambiguation", "routine adjustment" or "managing resource availability"), making it a potentially challenging case to categorise. Therefore, exploring it in more detail could help to disambiguate the boundaries of these categories.

(iii) *Work- On one of the online forms at work, a text box is very small and hard to read. I type into a larger text box and copy across when finished*

This item did fit within one category, however challenged the scope of the category in question ("routine adjustment" seemed appropriate, however the 'ad hoc/on the fly' nature challenged the manner in which the category description had been expressed).

(iv) *My scissors broke so I opened tough parcel with a sharp pen*

This item was seemingly not well accommodated by any of the items contained within the scheme, inviting the possibility of expanding scheme coverage by potentially introducing a new category or theme.

(v) *At home working and on the move- Calendar syncing does not work. To carry out my job effectively I need access to accurate calendar wherever I am. On blackberry and iPhone and MacBook Air as sync doesn't work I take a photo once a week of the calendar on my mac, and refer to the photo when need to look at dates*

This item also seemingly encompassed a resilient quality (creating an artefact that contains semantic information, rather than a mere cue) that was not well captured within the scheme, which again represented a potential opportunity to broaden coverage.

(vi) *Before leaving to go to the zoo, asked partner if he had his membership card, as would have been a waste of time driving there if not*

This item was one of two (the other being item (ix)) which involved a reliance on another individual, which we felt could raise a discussion on this 'social' aspect of

cueing, a theme we derived from these selected cases which was again not represented in the seven-item scheme.

(vii) *We were in a pub garden and it was much colder than expected. We made use of spare coats which live in the boot of the car. The coats had intentionally been there for that purpose so the 'moment of resilience' was probably months before when they were left there*

This item represented an unusual case in terms of timing, with the 'moment of resilience' occurring a significant length of time prior to the manifestation of the challenge to which it corresponds. It was intended that a discussion surrounding this could help us to better conceptualise the aspect of timing of resilience.

(viii) *Had forgotten phone charger- only realised in the evening just before bed. Phone had low battery so I turned it off to save some battery for the next day. Threat recognised was that I may have no phone battery left the next day and would subsequently not be reachable (added risk as I'd forgotten my wallet!)*

This item could perhaps best be categorised as "routine adjustment", however challenged the framing of that category by being more of an 'in the moment' reactive intervention rather than the adjustment of a 'routine'.

(ix) *After setting alarm on my phone, asked partner to set up a 'back-up alarm' on his own phone, in case mine didn't work for some reason*

This item, as with item (vi), incorporated a 'social' aspect in its dependence upon another individual, a feature that again was not discussed by Furniss et al. in the original scheme.

(x) *We were going for a walk and I am currently 'wearing in' some new boots. Even though it was a hot day, I wore extra thick winter long socks to reduce the friction from the shoes and provide padding. Reduced perceived threat of later discomfort*

This item was similar to item (viii) in so far as the most appropriate category to accommodate it was seemingly "routine adjustment", however the strategy seemed to challenge the manner in which that category title and description had been presented in the original scheme.

(xi) *When I was packing a bag at home before heading off for the weekend Saturday morning, I wanted to leave my laptop charging for as long as possible but ensure I didn't forget it. Left its case at bottom of stairs as a cue/reminder.*

As with item (ii), this strategy apparently simultaneously incorporated aspects of multiple categories (both of "cue creation" and "routine adjustment"), meaning it again represented an opportunity to better disambiguate these categories to reduce such a conceptual overlap.

Each of the cases here has been presented in the manner in which it was transcribed, which comprises the exact wording used in the diaries. Of these 11 cases, the majority (totalling 8) were composed by our pilot participants, while the remaining 3 cases were composed by the thesis author (items 7, 8 and 11).

In the following discussion, we consider in more detail the implications of our findings, both in terms of assessing the conduct of the exercise and suitability of the materials (returning to the piloting purpose of the activity) and we also consider some of the nuanced aspects of the 11 selected items in more detail. We also return to a discussion concerning our approach and describe how these cases, combined with the others raised in the workshop activity, informed our continuing thematic analysis of the different types of resilience strategies that exist.

6.3.7 Discussion of First Round

As described in 6.3.6, the output of this study can be considered in terms of both its implementation as a piloting activity to assess the approach and conduct of a diary study to collect real-world resilience strategies, and also in terms of the data gathered and taken forward to the workshop activity.

We therefore, as with our results above, structure the following discussion around this distinction, with the former portion discussing aspects of the exercise in terms of being a pilot (i.e. suitability of the approach, practical issues and considerations etc.) and the latter portion discussing the more notable strategy cases we selected for inclusion in the workshop.

6.3.7.1 Pilot Study Discussion

As described, this first round of data collection had initially been conducted as a pilot exercise, and was motivated in terms of assessing the potential suitability of a diary study approach, and developing such a method for the collection of resilience strategies.

Upon consulting the data obtained during this exercise, we are satisfied that the work serves to demonstrate the utility and value of adopting such an approach for the capture of resilience strategies. Despite the limited scope and small sample used here, the 66 entries we elicited compare favorably to earlier work in the area by Furniss et al. in terms of volume of recorded strategies, which is particularly notable given the limited 5-day duration of the exercise. Moreover, our collection of strategies contained a rich variety of different types of resilience, with a small selection deemed sufficiently insightful or novel so as to be able to be used in the theory building exercises described in Chapter 5.

While we would therefore deem this work to have been successful, we did encounter a number of aspects of our approach that could benefit from minor refinements, based on feedback from our limited sample and the first-hand experiences of the investigator.

As mentioned in 6.3.2., upon collecting participants' diaries, we conducted some brief follow-up discussions with our sample, providing a chance for qualitative feedback on the task. These discussions revealed that there was some ambiguity regarding the list of prompts used to elicit additional contextual information for strategy entries. Reflecting on the list of prompts, we felt that despite their propensity to introduce some uncertainty, they had overall been a worthwhile addition (an assertion that was backed up by feedback from one of our sample, who informed us that the prompts helped them to structure their entries). We therefore opted to keep the prompts in question, however to spend some time outlining them prior to providing participants with the diaries, as is later described in 6.4.4.

Another potential issue, raised by one of our sample but also encountered and noted by the investigator during their own conduct of the study, was that there was a minor difficulty in terms of the physical format of the diaries. While the paper diaries were necessarily very compact so as to facilitate carrying, the fact they were both small but also flexible (i.e. soft-bound and without rigid covers back or front) combined to make for a difficult format in which to write while on the go. While this would have been mitigated in cases where entries were composed at a desk or on a hard surface, it was noted that this still represented a minor difficulty in circumstances where this was not possible.

While representing less of an issue or practical difficulty, we also noted a consideration during the initial conduct of the pilot that we became mindful of, and which had a bearing on the final conduct of the subsequent diary study; catering for retrospective accounts of strategy use encountered prior to the commencement of the diary study. In the initial pilot, two subjects recorded entries which were observed prior to the study (i.e. recalling from memory the strategies they used, or observed friends and family using in the past). Such instances were still deemed to be useful and within the scope of the study, given that our motivation was not in investigating the frequency of occurrence per se, rather we sought to establish as broad and numerous a pool of strategy instances as possible. For the second round of the diary study, we therefore informed participants this was permitted though not required.

Reflecting upon the follow up discussions previously described, we also noted that these represented an opportunity to clarify any ambiguities or add supplementary contextual information in cases where a diary entry included insufficient information to draw meaning from. We found this practice to be more useful than anticipated in eliciting some additional information, however we also encountered a number of cases where specific features or details of a strategy were difficult to recall retrospectively.

The pilot study, in summary, proved to be a successful exercise both in terms of demonstrating the suitability of a more traditional paper-diary format in the collection of resilience strategies, and also in terms of assessing the format and setup we established for this purpose. While some minor amendments were made in response to the feedback gathered during this exercise, as are described in 6.4.4. below, from this pilot we were able to proceed with the diary study proper as later described. Moreover, and in perhaps an unanticipated 'bonus', we were also able to extract and apply some of the data gathered here in our collaborative theory-building work, which demonstrated the insight and value obtained from what had initially merely been considered a piloting activity.

6.3.7.2 Discussion of Data Used in Workshop

As outlined, considering the relative success of conducting the piloting activity, and the potential strength in terms of some of the entries we received, we opted to utilise a selected number of cases of data obtained here in a collaborative workshop activity as previously described in 5.3.2. While the data in our limited pilot exercise contained 66 resilience strategy records, we determined it would be impractical to take forward all of these cases for the workshop. This was because many of our strategy cases were relatively similar and analogous to each other, for example the establishing of simple cues to serve as reminders, which constituted many of our collected accounts. To request our workshop participants to categorise

each of these largely similar accounts would, we felt, potentially represent a laborious undertaking while yielding only very limited insight in return. We were also keen to incorporate strategy cases reported and collected by our co-organisers and other workshop participants, which had the advantage of incorporating a variety of other data-collection methods. For these reasons, we decided it was necessary to take forward only a limited subset of the accounts we collected during this exercise.

At this stage in the process, our primary motivation for the workshop exercise was to test and improve on the conceptual coverage of the scheme items. As such, we were primarily interested in strategy accounts that, by our interpretation, challenged the boundaries of the category descriptors or potentially were not represented by the existing scheme at all. The selections we made when taking our cases forward reflected this motivation, and were each deemed to be challenging to apply to the scheme, rather than a straightforward match to one of the seven categories originally proposed by Furniss et al. (2012). The task therefore became to select an appropriate subset of strategies to take forwards, by closely considering our collected entries against the Furniss et al. 7-item categorisation scheme (a process outlined in more detail previously in 6.3.5)

In some cases, it was perceived that our new strategy accounts might be accommodated by the scheme, but challenged the manner in which the initial scheme items had been described. For example, regarding cues, item 1 (writing notes to encourage citing) seemingly described the process of cuing for the purpose of directing attention, as opposed to memory (where it was explicitly stated that the risk of "forgetting" was not the primary motivation). This seemingly challenged the way in which Furniss et al. (2012) conceptualised 'cueing' strategies (as a means to mitigate frailties in memory; *"Cue Creation to Support Prospective Memory"*). It was therefore reasoned that the inclusion of such a strategy example might challenge the scope of this scheme item, potentially either broadening it to encompass cues as a means to support attentional as well as memory-related processes, or perhaps introducing a notion that may result in a new scheme item. Ultimately, as we discuss

previously in 5.4.2, the former of these was realised in our revised 10-item version of the scheme.

The second case we took forward (deliberately structured formatting of computer file names to assist sorting) also seemingly captured a resilience behaviour that may have been represented in the original scheme, but did not seem like an 'easy fit' into any single one of the seven categories. The restructuring of data to assist findability seemingly incorporated aspects of *"Separation and Disambiguation", "Managing Resource Availability"* and potentially *"Routine Adjustment"*. The observation that single strategy cases may contain aspects represented across multiple categories was a notion also seemingly applicable to item 11 (adapting steps in a bag-packing process) in particular, which seemingly contains aspects both of cueing and also routine adjustment. The inclusion of these cases thus was of perceived value as it may lead to a clearer articulation of the distinction between categories.

Item 3 from our selection (copying and pasting text to enhance readability) represents an interesting behaviour that demonstrates potentially the concept of routine adjustment, however here we noted a nuanced aspect of timing that does not seem optimally captured in Furniss et al.'s framing of the item. Furniss et al. describe such operations being enacted in cases where "…someone perceives a potential threat…", whereas in this case the strategy could more accurately be described as being used where 'someone has *encountered* an *actual* threat*'*. This distinction may appear subtle, however it raises questions concerning the 'moment of resilience' (as discussed previously in 2.3.3) and the notion of resilience as being anticipatory and forward-looking, versus reactive and a sort of 'coping mechanism'. A motivation to further explore this notion of when the 'moment of resilience' occurs also resulted in the inclusion of item 7 (the packing of 'spare' coats).

Item 4 (using a pen to open a parcel instead of scissors) captures a phenomenon we had encountered during the literature review, however that was not captured in the Furniss et al. scheme; that of appropriation. This is a feature also of items 5, arguably appropriating the screenshot functionality for a purpose not

originally envisaged, and item 11, in which the laptop case could be said to have been appropriated as a cue. As we discuss previously in 5.4.1, the inclusion of these items, along with others raised during the workshop activity, motivated us to expand the scheme by adding a new category to reflect appropriation in our enhanced 10-item iteration.

Item 5 (using a screenshot to duplicate important information) seemingly describes the creation of an informational artefact, a notion that is again not clearly present within the original scheme. While such a case could be said to fall under the category of *"Managing Resource Availability"*, it does not seem fully compatible with the category description; "Rather than helping the person remember, this strategy will compensate for forgetting". The threat present in the case of item 5 is rather a failing in technology, and again revisiting the notion of timing, the strategy is a reactionary response rather than an anticipatory one. It is cases such as this (and items 3, and 7) that stimulated discussions concerning this 'timing' aspect of resilience, and motivated our (ultimately unsuccessful) activities around framing the categories with a temporal step, as discussed in 5.4.

Both items 6 (reminding one's partner not to forget an item) and 9 (requesting one's partner sets a backup alarm) were included owing to their capturing a quality that, to date, we had not explored in any depth, that of collaboration and reliance upon other people. These items both comprised otherwise relatively simple instances of cueing, and of reinforcement, however it was their dependence upon the presence of another person that motivated their inclusion. With regards to the role of others in resilience strategies however, subsequent discussions with Jonathan Back and Dominic Furniss steered us towards reconceptualising other individuals as *resources* in the resilience strategies of individuals. To introduce the added complexity of including other human actors in the investigation of *individual* resilience strategies seemingly broadened the scope of investigations to a higher level of granularity, a concept we discuss previously in 3.5.

Items 8 (turning off phone to preserve and maximise available battery life) and 10 (wearing thick socks to wear-in new boots) seemingly both contained the

qualities described in "*Routine Adjustment"*, however as we discuss previously in 5.4.2, the application of the term 'routine' here implies an element of frequent or regular usage, when in fact these couple be considered examples in which a behaviour had been adjusted in an 'on the fly' manner (particularly in the case of item 8). This quality of improvised adaptation in the face of an irregular or unencountered challenge or threat was seemingly not well captured in Furniss et al. scheme. The inclusion of these items was thus motivated by a perceived potential to expand and broaden this particular category, a measure which we did indeed take when developing the revised 10-item version of the scheme.

A secondary motivation for including item 10 in particular was that it also comprised a case of what one might perceive as a non-resilience item, which represented a different form of 'edge-case', stimulating discussion as to what might or might not be considered within the appropriate scope of work on resilience strategies. This question of what is and is not considered resilience, earlier discussed in 3.5, also had implications for how we were to consider some of the entries gathered in the second round of our diary study, as described below.

6.4 Second Round of Diary Study

The initial piloting activity not only proved the concept of utilising a diary study approach in the collection of resilience strategies, but additionally provided data useful in our activities to begin developing and refining the Furniss et al. 7-item categorisation scheme for resilience strategies. While a subset of this data was used in the workshop to assess and expand the original 7-item scheme, there was a need to gather further accounts of resilience strategies to inform the composing of a new iteration of the categorisation scheme, and to assess and validate this new iteration (as described from 5.4.3. onwards). The data gathered during this second phase of the diary study served this purpose, and the exercise of collecting it was undertaken

following the workshop and concurrently with our efforts to produce and assess a new iteration of the categorisation scheme.

As discussed previously, the work of gathering this data as well as initial assessment and sorting was conducted solely by the thesis author, while the process of generating the revised iteration of the categorisation scheme was conducted collaborative with Furniss and Back. The data-gathering approach used here remained largely unchanged from that adopted during the pilot, with the exception of a small number of refinements and modifications we describe below.

6.4.1 Participants

The final sample for this study comprised an opportunity sample of a further 10 participants (6 female) of varying age and occupation, who were recruited via social media and in some cases referred by colleagues/pilot participants, or approached by the thesis author, owing to their occupation and perceived suitability.

Participants were each compensated to the value of £25 in the form of an Amazon voucher for their participation in the study, owing to the two-week duration and two face-to-face meetings it entailed (introduction and briefing, and collection of diaries/debriefing discussion).

While the total sample size of 10 participants could be interpreted as being a relatively modest sample, we arrived at this figure based upon the knowledge that the data collected via the piloting/first round was also to be rolled into our final dataset from the diary activities, and also based upon the time-consuming and 'involved' nature of the task, and the anticipated frequency of instances per participant.

6.4.2 Materials and Apparatus

As previously, participants were provided with a slightly amended *information and instruction sheet* including additional strategy examples, in order to assist in comprehension of the concept of what a resilience strategy was (available in Appendix C), a *ballpoint pen*, and a *paper diary* containing the same list of *prompts*

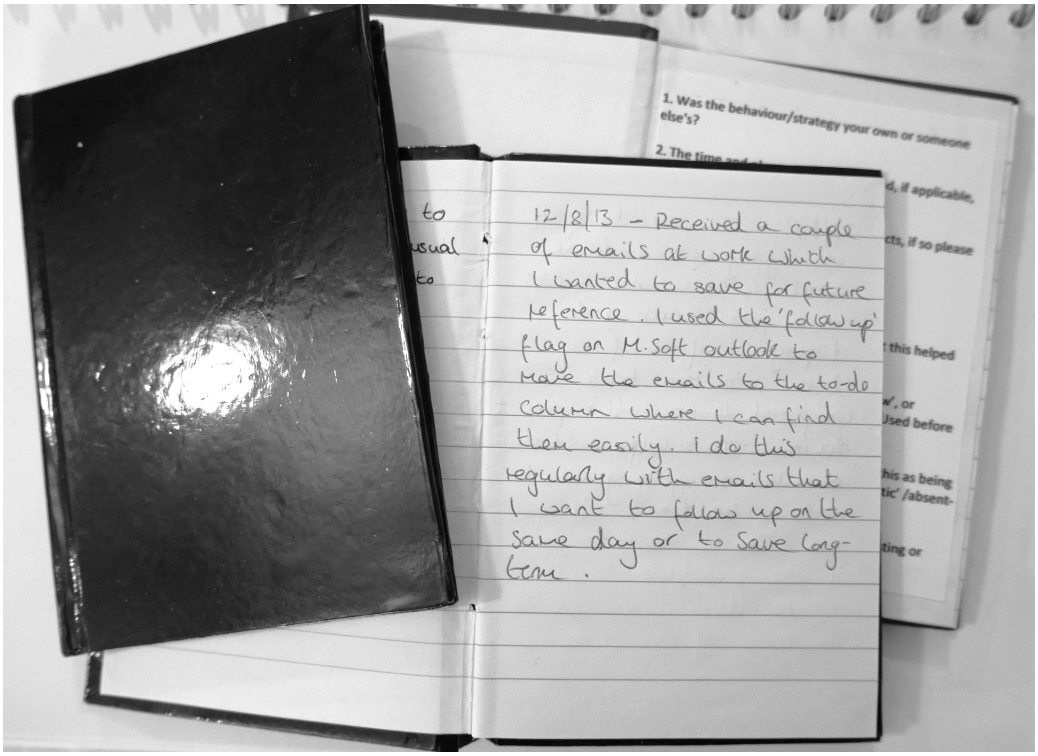


Figure 20. Diaries Used in Second Round

used in the pilot/first round. Responding to the finding that these prompts had been the source of some feedback concerns previously, we opted to take the additional step of explaining each of these prompts to each participant rather than removing or altering them, as we further discuss below.

One change we did make with regards to the materials used in this second round of the diary study was to use slightly different paper diaries, in terms of size and physical format (Figure 20). Responding to a concern identified by one of our pilot participants (and also noted by the thesis author from his first-hand experience in undertaking the exercise), we opted to use slightly larger (15cm x 10.5cm) diaries

that were hard-backed, in contrast to the slightly smaller (13cm x 9cm), soft-backed diaries previously used. This was to improve the ease with which entries could be written down, primarily in terms of providing added rigidity and stiffness for situations in which no hard surface was available to place the diary down on when composing entries. The marginally larger size of the diaries also slightly improved available space, however rather than opt for substantially larger diaries, we instead chose to retain a diary size that could be carried anywhere with relative convenience (i.e. in most trouser or jacket pockets) to facilitate the ability for participants to compose entries when and where resilience strategies were encountered.

6.4.3 Study Design

The design of this second round of the diary study remained essentially unaltered from that previously outlined (6.3.3), remaining a semi-structured diary study. The only substantive design element which differed between this second round of the investigation and the first round was in terms of the purpose of the exercise; this second round was no longer undertaken as a piloting activity, and was instead solely concerned with the collection of resilience strategies to inform analysis and revision of the Furniss et al. (2012) 7-item categorisation scheme for resilience strategies.

There was one component of the study design, described in 6.3.3, that we did consider changing or removing; the list of prompts used to elicit additional contextual information. This was in response to pilot feedback that suggested some of the prompt items may be difficult to understand, or that participants may be concerned that they did not address each of the items. At the same time however, another pilot participant had described how they had actually found the prompts useful in guiding the composition of their entries.

We ultimately reasoned that even if only some of the sample found these prompts to be a useful addition, and even if they only elicited limited additional insight, this would still represent justification for their inclusion. We therefore opted

to retain the prompts, however adapted our task procedure to include an explanation of each prompt in order to assist with comprehension and understanding.

6.4.4 Task Procedure

The task procedure again remained consistent with that previously described in 6.3.4, however the following minor alterations were made:

- In terms of providing participants with instruction, we lightly amended the participant *information and instruction sheet* by rephrasing the introductory paragraph and enriching our definition of resilience strategies with examples.

- As noted, when conducting the initial briefing, we also went through each of the prompts individually to describe their meaning and purpose, and ensured participants understood each item in the prompt list. We also made sure to reiterate that engagement with the prompts was optional, that they were merely a tool to guide content (mitigating any potential risk of participants finding the prompts discouraging or a 'barrier' to including an entry).

- Also in response to observations from the pilot, during the initial briefing we made clear to participants that retrospective entries would be acceptable, and that they could contribute strategies they recalled encountering prior to their participation in the study.

- The study duration was 2 weeks for this second round of the investigation, compared to the 5 days of the first round (owing to the first round having been initially conducted as a pilot).

- Upon collection of the diaries after the 2 weeks, the 'debriefing' conversation with participants involved brief follow-up questioning, structured around the

content of the entries provided, in order to clarify any ambiguities in entries or add any 'missing' potentially relevant contextual information.

6.4.5 Data Analysis Approach

Different selections (so as to minimise the direct re-using of a limited number of cases) of the strategies we captured during this second stage of the diary study were used to: (i) inform the creation of the revised and expanded 10-item categorisation scheme (described in 5.4.3), (ii) contribute to the validation activity of the 10-item scheme (5.4.4), and (iii) contribute to our activities to explore adding a temporal framing component to the scheme (5.5). Across these activities, the data was therefore used both inductively and deductively at different stages of our process. In terms of inductive analysis, the entries gathered during this diary study contributed to the expansion (adding new resilience concepts and categories) and refinement (helping to explore boundaries and overlap between categories) of the revised scheme, as well as contributing to the introduction of temporal framing. Deductively, the data was initially analysed against the existing 7-item scheme in order to identify the most appropriate and insightful cases to take forward in our subsequent activities, and also served to inform our analysis and assessment of the revised scheme (including the temporal framing version of the scheme).

In terms of the practical activities involved in analysing the data collected here, the data from this second round of the diary study (totalling 158 cases) was transcribed and then merged with the data from the first round to produce a composite dataset of all diary study entries gathered through both stages of this investigation.

Our next step was then to individually consider each case, with a view to identifying and excluding instances that were either (i) considered non-resilience items, or (ii) represented explicit duplicates. Regarding the exclusion criteria for duplicates and non-resilience items, explicit duplicates *within* subject entries (for example, where a post-it note had been used in the same way on multiple days and

logged each instance) were removed, however apparent duplicates *between* subjects were not excluded for the sake of potentially later exploring the prevalence of certain types of strategy across the sample. The identification of non-resilience items involved conservatively flagging and excluding items that seemingly contained no discernible resilience-related qualities as articulated from our literature review, however this was a somewhat tacit and subjective process, a subject we later revisit in our evaluation (6.5). Returning to Braun and Clarke's (2008) structured approach to thematic analysis, the activity here corresponds to their first of the six phases, "Familiarising yourself with your data".

Following this, the thesis author conducted a first-pass deductive analysis activity to assess the diary entries within the context of Furniss et al.'s initial 7-item scheme. This took the form of attempting to categorise each of the collected strategies within the scheme, and as previously, flagging items that proved challenging to categorise (as described in 6.3.5). The process of again identifying and selecting these 'edge case' examples could be considered analogous to Braun and Clarke's second phase of thematic analysis, "generating initial codes". Braun and Clarke describe this as "Coding interesting features of the data in a systematic fashion across the entire data set", however we would consider each such item to represent its own code in our adapted approach, meaning at this stage in the process we were more accurately *identifying* interesting features of the data in a systemic fashion, rather than abstracting them into codes.

Each of these 'edge case' examples were taken forward and, in combination with the output from the previously described workshop activity (5.3, which had itself also been partially informed and supported by the data from the first round of the diary study as described in 6.3), was used to inform the collaborative theory-building process of formulating the revised 10-item iteration of the categorisation scheme. This work, encompassing activities analogous to phases 3 to 5 of Braun and Clarke's thematic analysis approach (corresponding to *Searching for*, *Reviewing*, and *Defining and naming* themes) forms the subject of 5.4 and as such, will not be

duplicated in this chapter (however we do describe some of the direct contributions of our diary study entries towards this work in the results section following).

While this comprised the core of our process in deriving theoretical insight from the data gathered in the current diary study, some of the entries we captured here were also leveraged in our subsequent activities to assess the new iteration in an inter-rater reliability activity. Furthermore, the data collected here also contributed towards the introduction of our temporal framing component, and later testing the resulting adapted temporal-framing scheme in a further inter-rater assessment. Again, these activities, representing primarily theory-building work, are primarily discussed in 5.4 and 5.5 and are thus not replicated in this chapter. We will however revisit these briefly in the following results and discussion, with specific reference to the data collected here, and the selection of instances taken forward for these purposes.

6.4.6 Results

In this second round of the diary study, participants composed a total of 158 entries across all 10 diaries. As described however, we amalgamated the data from the first and second rounds of the diary at this stage to produce a unified pool to inform our subsequent theory-building work. This combined pool of strategies therefore totalled 224.

Based upon a cursory inspection of the data by the thesis author and adopting a process described in 6.4.4 previously, 31 entries were excluded on the grounds of explicitly representing duplicates, while a further 7 entries were excluded as they were deemed to be non-resilience items. The number of instances of resilience therefore carried into the main data set (and considered in the analysis described below) was 186.

The next step we took was to apply the original 7-item Furniss et al. categorisation scheme to this data, in order to assess how well our diary entries aligned with that scheme, and in particular, to highlight cases that did not fit well

with the scheme which may represent novel resilience strategy concepts not represented in the scheme. While we assigned category labels in a 'best fit' manner to the strategies, we also noted cases where we felt there was some level of ambiguity, or where it appeared the case that a strategy could be categorised under two or more labels, as we reasoned these also represented potentially useful cases in developing the revised iteration of the scheme, by facilitating consideration of the scoping of, and boundaries between, category items.

Specifically regarding the data gathered during this second stage of the diary study, we also noted the number and variety of entries varied considerably between subjects, ranging from 8 entries spanning 3 categories up to 35 entries across 6 categories. The frequency of strategies for each category is summarised in Table 6, while the individual category selection for each entry is available in Appendix D under the column "Furniss et al category". Notably, a total of 9 strategies were additionally deemed to fall outside of the Furniss et al. categories, as reflected in the table.

As expected, only a few categories can account for the majority of instances of resilience recorded, a finding which is in line with Furniss et al.'s own results and

Strategy Category	**No. Instances**
Cue Creation to Support Prospective Memory	62
Premature-completion Awareness	4
Pre-emptive Separation and Disambiguation	4
Pre-commitment Check	8
Managing Resource Availability	53
Routine Adjustment	36
Reinforcement	10
Miscellaneous/None of the above	9

Table 6: Distribution of Different Types of Strategy

the noted trend that certain types of strategy (particularly those involving cueing) are more prevalent, or perhaps at least, easier to recognise and/or recall. Whether this is due to their actual frequency or rather their salience (in terms of being comparatively tangible and concrete) is an issue we revisit in the evaluation presented in 6.5.

Of particular note and perceived value from this exercise were the 9 items that seemingly could not be categorised using Furniss et al.'s 7-item scheme. These 9 items, as well as a number of other instances from our diary study data that seemingly were able to be allocated to multiple categories (and so raised potential ambiguities in framing or scoping of categories) were taken with the output from our aforementioned workshop, and served as the foundation to inform and structure our discussions and collaborative theory-building work from which the revised 10-item scheme was derived.

Here, we present each of the 9 entries and provide a brief summary of how each was problematic within the context of the 7-item scheme, and how each contributed towards the development of the 10-item scheme outlined in the previous chapter.

(i) *Mental lists, repetition when unable to access paper or phone*

This particularly brief example was noted as a 'placeholder' in one of the diaries, having been composed shortly after a phone call during a busy period, when circumstances did not allow for the participant to compose a more detailed entry. By requesting more detail upon debriefing, we learned of this situation and of the meaning of the strategy. Our participant, working in a pharmacy, explained that they had just been given a short inventory of stock items that required checking, however did not have a pen or paper immediately to hand as they were on the pharmacy shop floor, and could not record the list in their phone handset as they were using it to place the call. The participant described how they repeatedly mentally rehearsed and internalised this list, in a step which again constituted a manifestation of the 'phonological loop' previously described in chapter 3.4.5. This type of strategy or

behaviour was not seemingly captured within any of the items of the 7-item scheme, however in our 10-item scheme constitutes an example of 'Adjusting a procedure or behaviour', which represented a conceptually broader reiteration of 'Routine adjustment' as described in the original scheme.

(ii) *I write a shopping list in area/section so that when I go shopping I do not forget anything and tackle it as quickly as possible*

This second example again required clarification upon debriefing. In this case, the participant describes the creation of a list, and the process of organising that list in terms of the store layout (grouping for example fruit and vegetables, sundries, frozen items, etc.). While an element of 'separation and disambiguation' is inherent in this strategy, we felt that the essence of the strategy more concerned the foresight applied to the creation of a cognitive artefact, which was a concept that had been discussed previously with Furniss and Back. This case, taken in combination with other similar cases discussed during the workshop activity, therefore contributed to the creation of a new categorisation scheme item; 'Creating new artefacts'.

(iii) *Labels placed on boxes of medication, representing that they have been issues they have an audit number, which we can use to trace on our dispensing system. In this case I used this audit number to credit the medication back to stock as it was not required on the prescription. To remind myself to do this I placed the label on my computer screen, whilst depositing the stock back to our storage. Doing this allows me to carry on with my current task as long as I have the audit number on the label I can then at a time convenient for me in my work then return and audit these items back into stock.*

Upon further discussing this strategy with the participant who composed it, we ascertained that the strategy described here did not represent a regular routine but was rather an on-the-fly adaptation of working process in response to a particularly busy period. We therefore reasoned that while this strategy was similar to the notion

of routine adjustment, this represented an example, as previously described, where the adjustment was applied less to routine and more in an ad-hoc manner to a previously unexampled event. This again contributed towards the reframing of 'routine adjustment' into 'Adjusting a procedure or behaviour', however additionally incorporates elements of 'Managing resource availability' in the placing of labels.

(iv) *Repeating words out loud multiple times when learning new vocab in foreign language while on holiday*

This entry represented another example of utilising the phonological loop to assist with retaining information, representing what the thesis author had previously termed 'intentional verbal rehearsal' when it had been observed in the initial probing study. Again, this is a concept which demonstrates a resilient quality (albeit perhaps more in a 'behavioural' sense rather than 'strategic') which is not captured or articulated within the 7-item scheme, however is encompassed by 'Adjusting a procedure or behaviour' in the revised 10-item version of the scheme, owing to it representing a behavioural adjustment in response to an anticipated vulnerability (i.e. frailties in memory).

(v) *While at work I often stumble across interesting articles. If I don't have time to read them, I'll leave them in a tab and come back to them later during some downtime. This also applies to tasks I have to do that involve web pages. This prevents me wasting time between projects I'm working on.*

This entry, representing what may initially seemingly represent a relatively straightforward strategy, actually contains aspects of multiple concepts described in the Furniss et al. scheme. The intentional action of leaving the tabs open as described simultaneously represents a cueing behaviour and the adjustment of a routine, however an important further feature of the strategy is also described in terms of its motivation; to defer actions and revisit them at a later stage. This notion of micromanaging workload is not well articulated in the 7-item scheme (even in terms

of its conceptually closest concept of routine adjustment) and was therefore included owing both to its apparent suitability across multiple scheme items and the perception it may introduce a new concept. In our newer 10-item iteration of the scheme, this however represents an example of 'Managing resource availability' owing to the workflow being reoriented around the management of the availability of the informational resources being considered.

(vi) *People write CVs with deliberate omissions. This means they can predict questions likely to occur in the interview and can rehearse answers*

During collaborations with Furniss and Back, the extent to which this does or does not comprise a resilience strategy was discussed, returning us to the question of how to conceptualise non-resilience items (later discussed in 6.5). The fact it demonstrates a behavioural adaptation to enhance performance in an envisaged future scenario does, in the view of the thesis author, conform to the way resilience is conceptualised at an individual level. Working on the basis that this does represent resilience, it seemingly demonstrates a quality not captured in the 7-item scheme. The nature of the 'threat' in this case is ill-preparedness in terms of ability to suitably answer interview questions, meaning the act of preparing and rehearsal for such an interview could be said to represent a barrier. Under our 10-item scheme, this strategy therefore represents a (perhaps somewhat unconventional) implementation of 'Reinforcing an existing safety barrier'.

(vii) *When I moved flat, I took many photos of the new flat in case there were any disputes on the state of the flat when I moved out*

This entry, demonstrating foresight of a potential risk and developing an adaptive behaviour to address it, again constitutes what, upon first glance, may appear a relatively straightforward example of a resilience strategy, however there is no immediately appropriate category in which to place it within the 7-item scheme. Within the revised 10-item scheme however, this strategy falls under the category of

‘Appropriating a resource’ in the appropriation of the smartphone camera as a tool to achieve resilience.

(viii) *My elderly grandma's TV remote control has had all but 3 buttons covered up so she does not get confused*

This strategy represents simplifying a task (specifically, a physical object) in order to enhance performance, in this case minimising the perceived risk of an incorrect button being pressed. While this again could be said to represent a relatively simple intervention, it does not appear well accommodated with the scheme. The ‘resilient quality’ of this strategy lies in disambiguating items (buttons) on the remote control, and as such we would argue that the ‘Separating task items’ category within the revised 10-item scheme would be applicable in this case.

(ix) *I have to reel off card details in public quite a bit, so I usually make sure before making a phone call that may involve paying for something, I have somewhere to go. At <anonymised> it was the private dressing room. Where I work sometimes there is a phone box just outside so I use that. It has to be somewhere where they can hear me, but passers-by can’t. If I want to sound like I am in an office i put them on hold until I am somewhere quieter*

In this case, the participant in question has developed a strategy which involves identifying locations where privacy can be assured, in order to reduce the risk of confidential information being obtained by a third person or party. While the strategy was most closely related to the label of routine adjustment, we reasoned it represented an unconventional manifestation of the category, displaying a resilient quality potentially not adequately captured in the category descriptor and one which could be applicable beyond the context of ‘routines’ and more as a reactive, ad-hoc and improvised behaviour or strategy. Thus, within our 10-item scheme, we would again classify this strategy as ‘Adjusting a procedure or behaviour’.

Upon developing the categorisation scheme into its new 10-item iteration, as discussed in more detail previously in Chapter 5, our next step was to collaboratively conduct an inter-rater assessment of the new 10-item version to assess the suitability and reliability of the revised scheme. This involved asking other raters to apply the scheme to a collection of some 80 resilience strategies, which again necessitated the selection of a number of instances of resilience strategy use.

As discussed previously in Chapter 5, in an effort to draw as wide a variety of strategies as possible for this purpose, four researchers (including the thesis author) each contributed a set of 20 strategies, which had been sourced from studies that spanned a variety of methodological approaches. Returning to the data gathered in this second round of the diary study, a total of 12 cases were selected from our second-stage diary study entries. These were combined with 4 strategies from the first stage of this diary study presented earlier in the chapter, and another 4 from the initial laboratory study (presented in Chapter 4) to form the thesis authors' allocation of 20 strategies (available in Appendix B2), for the cross-validation exercise.

Reflecting our stage in the process, and the fact we had moved onto the role of *assessing* the new scheme as opposed to actively developing it, these cases were selected not on the basis of representing edge cases (although a number were still included, hence the addition of the stage one diary entries) but instead were selected based on perceived variety, with the intention being to provide raters with a broad selection of different types of strategy to assess against the revised 10-item scheme.

While one approach may be to have conducted a reassessment utilising the prior 9 'problematic' cases, since we had closely used these as a template to form our amendments and the raters had encountered them previously, we opted to make a second selection of previously unencountered strategies. From our second round of the diary study, we selected the following 12 entries, which are presented here along with a brief summary of how they were applied by our four raters.

(a) *My mum can't hear the business phone ring from the kitchen. So she uses baby monitors in study and kitchen so she can hear the phone go and just about make it there in time to answer it.*

There was a high level of agreement in this case, with all raters categorising this strategy as 'Appropriating a resource'.

(b) *I have moved into a new flat and have 2 keys which are indistinguishable. I have moved one key next to my keychain so that i can identify which is which.*

Again, a high level of agreement was observed for this case, with all raters considering it an example of 'Separating task items'.

(c) *Work- I have purchased extra chargers for electronic devices which I keep with me at all times. This is most important for my mobile phone.*

This entry was also categorised with a high level of agreement, will all raters considering the entry as an example of 'substituting a resource'.

(d) *At work, I get assigned 'footprints'. On receiving, I use outlook's colours to mark the footprint as relevant, not relevant or urgent. I then use the 'flag' system in Excel as follows: flag = to-do, ticked = script written (follow up on next Monday), blank = no action needed. This combination covers all scenarios and makes it easy to see what needs to be done.*

All raters considered this strategy to be an example of 'Separating task items', reflecting again a high level of agreement. Our colleague Jonathan Back did however flag this strategy as additionally containing elements of cue creation and appropriation as well, a subject we consider in the discussion later.

(e) *Work/home- I leave windows open on my desktop to ensure I do not forget to read/act on the contents of windows. My PC at home is usually left on hibernate so as to preserve the windows.*

Raters again expressed unanimous agreement in determining this strategy to be an example of 'Managing resource availability'.

(f) *Wrote a to-do list for the week, so as not to forget to do any important tasks.*

A full level of agreement was again reached here with all raters considering this to represent an example of 'Creating new artefacts'.

(g) *As a trend I make use of sticky notes on my laptop and iPhone, writing ideas, movies I have to watch, errands I have to run.*

Again, all raters also considered this to be an example of 'Creating new artefacts'.

(h) *Leave letter that I need to scan and email next to laptop so I don't forget to do it. Conscious intentional.*

All of our raters again expressed a high level of agreement in this case, categorising it as an example of 'Creating new cues'.

(i) *Placing software toolbars so to remind you to use them rather than going through 'edit' etc.*

As above, all raters considered this to represent an implementation of 'Creating new cues'.

(j) *Our timer for the hot water tanks is broken so we rely on manually switching on/off when we need hot water. It's easy to forget to turn them off after use, because*

they are in a cupboard. We leave the cupboard door open when switches are on- to provide a cue to reduce the risk of forgetting.

This strategy presented a discrepancy in how it was categorised by raters, as one rater considered to be an example of 'Creating new cues' while our remaining raters considered it as 'Pre-completion awareness'. This is a case we revisit in the discussion following.

(k) *Editing and saving a document on laptop, which I considered to be important. As opposed to just saving the one copy or making one backup, I saved several copies in a few different places. Redundant copies reduced risk of data loss and made it easier to locate in future.*

Each of our raters categorised this strategy as an example of 'Reinforcing an existing safety barrier' reflecting a high level of agreement, however a remark was made by one rater with regards to the phrasing of the category descriptor, a point we again revisit in the discussion.

(l) *Went to a few music concerts- noticed drummers frequently have a 'pot' with several spare drum sticks*

All raters categorised this strategy as 'Managing resource availability', representing again a high level of agreement in this case.

The data gathered during this second round of the diary study was used in a final, third way during the theory-building work presented in the previous chapter. Upon introducing the notion of temporal framing to the scheme, we again conducted an inter-rater assessment, as described in 5.4.3 previously.

For this purpose, we used an expanded collection of resilience strategies, which included the 80 strategies used in the initial inter-rater assessment, as well as a further 40 strategies. The 40 additional strategies used for this purpose, available in

Appendix B2, were gathered exclusively by the thesis author from this diary study data, and again selected based on perceived variety by the thesis author.

6.4.7 Discussion

The data gathered during this second round of the diary study proved to be invaluable in informing our theory-building work into the development of the categorisation scheme in several ways. Firstly, we were able to extract a number of edge-case examples, including some that captured resilience strategy concepts not contained in the original Furniss et al. 7-item scheme. These diary entries helped to inform our scheme refinement activities, which expanded scheme coverage by introducing new items, with edge case examples also helping to shape our framing of how individual categories were scoped and described. Secondly, a further selection of the diary entries collected here provided us with material for 'testing' the scheme once it had been refined, in terms of offering us a varied collection of real-world strategy examples to support our inter-rater analysis of the 10-item iteration of the scheme. In a third-round of theory building activities, the diary entries again served the role of providing a corpus of data to support our efforts to assess the scheme once we had introduced the concept of temporal framing, although as discussed in 5.5.3., this was an addition to the scheme which we ultimately chose not to take forwards.

Owing to the iterative nature of this work, the results section above reflects the multi-stage process in which the data collected here served to inform our conceptual work, which is itself discussed in more detail in the previous chapter. Owing to much of our theory-building work being previously discussed, as well as cursory discussion of our diary entries in the results section above, we provide only a limited further discussion here which focuses on some specific cases of where our diary data has most informed the development of the scheme, demonstrated the improvements made in our second iteration of the scheme, and also where it reveals some limitations or ambiguities in the scheme which persist to this point.

With regards to how our diary entries helped to expand the coverage of the scheme, perhaps the most salient examples are two cases in which new scheme items have been introduced that describe resilience concepts not captured in the earlier Furniss et al. 7-item first iteration of the scheme.

Our entry (ii) *"I write a shopping list in area/section so that when I go shopping I do not forget anything and tackle it as quickly as possible"* describes the creation of shopping lists, a relatively straightforward manner in which people create semantically rich artefacts to support memory. In the 7-item iteration of the scheme, this is perhaps best represented by 'cue creation', however by more closely considering an expanded pool of real world strategies, it becomes apparent that a meaningful distinction can be made between simple cues that are generally used as a placekeeping aid, and artefacts that contain more semantically rich information. Analysing resilience at this newer level of granularity helps forward our understanding as we can consider the implications of this distinction in how and why strategies work, and why one strategy may be 'more' resilient, while another may be more frail. This deeper level of analysis helped move us towards the work later described in Chapters 7 and 8.

Entry (vii) *"When I moved flat, I took many photos of the new flat in case there were any disputes on the state of the flat when I moved out"* describes a participant utilising their smartphone camera to create a record of the condition of a residence, prior to moving in. This represents one among a number of examples (which were also raised during our workshop activity) that capture the appropriation of items as a means to assist resilience, a concept that was again not articulated within the earlier 7-item iteration of the scheme. As the scheme fundamentally serves as a means of identifying and considering aspects of resilience, this case again represents an example of how the data from this diary study has contributed to the improvement of the scheme in our second, 10-item iteration, by expanding the coverage of the scheme to include a new concept not previously captured.

As well as informing the introduction of new scheme items, the data from this second round of the diary study also helped to inform refinements made to the

phrasing of scheme items, which resulted in improvements in terms of scoping and defining the boundaries of scheme items. For example, entry (iii) whereby a pharmacist placed medication labels on the side of a monitor whilst preserving important audit numbers, described an ad-hoc and improvised adjustment of working practice that informed our move towards reframing 'routine adjustment' into 'adjusting a procedure or behaviour', which better reflects the fact that not all such strategies represent a 'routine' or rehearsed activity, and such cases can be observed in previously unexperienced events and circumstances. Similarly, item (viii) whereby TV remote buttons were covered up, contributed to us reframing 'pre-emptive separation and disambiguation' into 'separating task items' which broadened the scope of this category, reflecting our observation that such strategies need not always be *pre-emptive* in nature, and can be reactive.

The data gathered during this second round of the diary study also provided us with an additional selection of strategies we could use to assess the revised 10-item iteration of the scheme, without having to resort to assessing improvements based upon the same strategies we had considered when developing the scheme. By collecting such a large number of varied real-world strategies, we could therefore avoid the potential issue of 'recycling data' between our development and assessment activities.

With regards to assessment, cases (f), (g), (h) and (i), which each describe either the composition of cues or of artefacts, helped to validate our separation of the concepts of cues and artefacts, and the introduction of the 'creating new artefacts' category. The high levels of agreement observed across raters in assessing these cases helped to demonstrate that raters can disambiguate between the two conceptually similar principles, the articulation of which was a feature lacking in the earlier 7-item iteration of the scheme.

Case (a) described the appropriation of a baby monitor to help in hearing a doorbell from some distance away. Such a case again does not seem to be well reflected in the original 7-item version of the scheme. While one could perhaps apply the *Routine Adjustment* category here in a generic manner, this does little to reflect

the behaviour of interest which such a strategy demonstrates, that of appropriation. The new *Appropriating a Resource* descriptor captures the essence of such a strategy in a much clearer and more accurate way. The examples provided here therefore lend credence to the modifications we made to our revised 10-item scheme, which we feel better represents and reflects such cases. Moreover, the full agreement of each of our raters in categorising this case indicates that strategies involving appropriation, a new introduction as a resilience concept, can be readily identified (an assertion which was reinforced by other examples outside of this diary study data in our inter-rater assessment)

While the introduction of a temporal framing aspect to the categorisation scheme proved to be less of a success (for reasons we explore in more depth previously in 5.5.3), the data gathered during this second round of the diary study still served a valuable additional purpose in assessing the temporal framing iteration of the scheme. The following case, for example, served to illustrate issues which arose when trying to apply this temporal iteration:

> "Was driving the car when I remembered I had an important, time critical email to send. I didn't want to stop the car or forget to compose it, so I tapped 'email' and 'compose' on my phone so when I parked up and looked at my phone next, I would have a visual cue to remind me (an empty email)"

When applying the temporal framing step as discussed in 5.5.2, this was one of a number of cases where our raters disagreed in assessing the temporal framing of the strategy. Two raters interpreted the strategy to be anticipatory in nature, owing to the threat in this case being perceived as forgetting to compose the email. However, one rater interpreted the strategy differently, seeing it as reactive, owing to the fact that the particular strategy used was a response to the circumstance in which the strategy author found themselves in at that moment (i.e. driving, an unavailable to complete the task immediately). Our fourth rater determined that the strategy was neither responsive nor anticipatory but stood independent of this distinction.

Examples such as this helped to illustrate how our preconceptions when introducing the temporal framing, primarily that the task of assessing temporal relationship to threat would be relatively straightforward, proved not to be accurate.

While the revised 10-item scheme we take forward represents a marked improvement in terms of coverage and clarity (as demonstrated by the activities described in the previous chapter and supported by this diary study data), it is worth reflecting that some limitations and ambiguities persist with the scheme. The diary entries we gathered here can help us to consider and explore some of these.

Cases (j) and (k) for example imply that further refinements could potentially still serve to benefit the categories of 'precompletion awareness' and 'reinforcing an existing safety barrier'. The former case (leaving a cupboard door open to signify a switch being left on) has been a source of some contention throughout the process of developing the categorisation scheme (as previously indicated in 5.4) as it can be seen to represent a different framing of resilience, owing to it being a rather threat/risk-oriented expression of a category. This may to an extent explain the inconsistent response to it in our inter-rater assessment, with strategy (j) being conceptualised by one rater as a cue (with an emphasis on the resilience response) while the remaining raters focused more on the anticipated resilience threat or challenge (representing a post-completion error, and thus accounting for the selection of precompletion awareness). Case (k), saving multiple redundant versions of a file, represents a more minor consideration; that the notion of an *existing* safety barrier may artificially restrict the scope of the category in so far as the original action of *first establishing* a barrier may also represent appropriate resilience strategies. This aspect of the framing of 'reinforcing an existing safety barrier' is one we will consider in more detail and may be subject to revision prior to a publication currently in progress.

Case (d) described using onscreen colour and flag assignments to organise items, and illustrates a different potential issue, representing one instance in which it appears that a degree of 'conceptual overlapping' is still present, and describes a complex strategy case that simultaneously involves 'Separating task items',

'Creating new cues', and 'Appropriating a resource'. Returning to the context in which the categorisation arose however, it is worth noting that the scheme was never intended to represent a rigid taxonomy of discrete different types of resilience, rather it has been conceptualised as a framework to provide structure and facilitate analysis through articulating themes across strategies and providing a vocabulary for their discussion. The fact that some edge cases persist and the categories may not be totally mutually exclusive therefore does not mean that the revised scheme is not a useful contribution in terms of achieving its intended aims. Indeed, as demonstrated by our work thus far, the revised iteration of the scheme represents an important development in articulating new concepts that were previously unaccounted for, and providing increased clarity in terms of the existing and revised scheme items. Building on this work, and exploring the notion of strategies simultaneously belonging within multiple category groupings, we discuss further work in the following Chapter that serves to deconstruct strategies into more granular units of analysis that helps us to account for strategies featuring multiple resilient qualities.

Ultimately, despite (and perhaps more appropriately, *because*) some of our diary data exposing limitations in the various iterations of the categorisation scheme, the entries gathered throughout the course of this diary study have facilitated development and contributed towards an improved 10-item version of the scheme.

6.5 Evaluation and Contributions

The current chapter presents a two-stage diary study that was used to gather a broad variety of everyday resilience strategies, in order to inform iterative development of our theory-building work to expand and refine the categorisation scheme as described in the previous chapter. In gathering a large number of such strategies, which we were able to leverage in order to develop the scheme (both in terms of broadening coverage and better defining and scoping existing concepts) we would deem this work to be successful in terms of achieving its intended aims. In

this evaluative discussion, we revisit some of the issues we encountered during this process, before closing with a summary discussion of how this unit of work could serve to inform further analysis of resilience strategies.

One aspect of the study we wish to revisit regards the analytical approach deployed, in terms of Braun and Clarke's (2006) thematic analysis. As noted in the text, while one can loosely map our stages of analysis onto Braun and Clarke's 6-stage process, some of our work represents steps *conceptually analogous* to the thematic approach as opposed to representing a formal and direct application of it. This was a necessity, however, given that Braun and Clarke describe a process whose purpose is to generate themes from the ground up, while the purpose of our activities was to assess and develop a set of themes that had already been identified. By combining a data-driven, inductive approach (deriving new themes and scheme items from examination of the data) with a theory-driven, deductive approach (in application of the scheme during assessment activities), we acknowledge that our analytical approach represents an *adapted* application of thematic analysis. Given the absence of a suitable 'off-the-shelf' alternative that met our requirements and catered for our process however, this was a necessary approach.

Another aspect of the study we wish to revisit concerns the identification of so-called 'non-resilience' items; instances where participants recorded a diary entry that did not seem to represent a resilience strategy or behaviour. Previous work in gathering resilience strategies has almost exclusively involved their identification by a researcher seeking to identify such strategies (and while Furniss et al. applied a self-report method, their sample consisted only of researchers). This approach of using informed researchers to identify and gather strategies intrinsically leads to a somewhat implicit 'filtering' process in taking forwards only items that represent resilience cases. Our approach of self-report using a lay sample introduces a heightened probability of non-resilience instances being recorded, which requires us to consider how such cases can be identified. Given that ambiguity still surrounds aspects of the definition of resilience strategies, this was somewhat problematic.

For the purposes of this work, items were deemed not to be resilient if they contained no discernible resilient qualities as per described in the definitions of resilience previously presented in our literature review. The process of identifying such cases was therefore subjective and relied upon a degree of interpretation. Given the nature of the exercise, the broad 'everyday' scope and phrasing of the strategies in question and the still-transient nature of the phenomenon of resilience however, it is difficult to see how a fully objective approach could be undertaken to achieve these means. This is therefore a topic that will likely persist in future and is worthy of consideration by researchers or practitioners working within the area of individual resilience. The exercise of 'scoping' resilience, moving forwards, can however be enhanced by precisely the type of theory-building activity being undertaken here.

Considering the approach of applying diary studies as a method for the collection of resilience strategies, one further consideration, is that, as we alluded to earlier, certain types of strategies appear far more prevalent than others. This is an observation that was noted in early work within this area (e.g. by Furniss, Back and Blandford, 2012). The extent to which this is an accurate reflection of the actual prevalence of resilience strategy use, versus a potential bias in the way certain types of strategies are perhaps more recognisable or more likely to be reported, would require further investigation.

From observing participants in our opening laboratory study, we note that some resilience strategies and behaviours are less likely to be articulated (e.g. the dynamic readjustment or reorganisation of workload and subtasks, or the use of verbal utterances and rehearsal to assist working memory) and arise only upon observation by a third party. Such a point does draw into question the suitability of using exclusively self-report methods to elicit strategy reports, however in this case it is worth reiterating that to inform our theory-building work as described in the previous chapter, the diary study data discussed here formed only part of a wider collection of data which had been gathered using a range of methods (i.e. situated observations and task/workplace analyses, interviews and the extraction of instances from survey data) to broaden and enrich this pool of data.

While we would assert that self-report data should be combined with strategies obtained using other data-gathering approaches to ensure a full breadth of strategies is captured, the work in this chapter has served to demonstrate that the utilisation of diary studies can yield a relatively high frequency and broad variety of resilience strategy accounts, a finding which in itself arguably represents a minor contribution to the field. As discussed earlier in the chapter, one must remain mindful that the 'outsourcing' of the collection of resilience strategies can however reduce control over the reporting of potentially valuable contextual information. Therefore, it is important for an investigator to assume an active role in counteracting this and ensuring strategy accounts are suitably supplemented with important details. In the work discussed here, this is represented both in terms of the probes used to structure accounts and elicit details, and follow-up conversations and interviews to supplement strategy accounts with relevant additional information.

In closing, we would assert that the work described in this Chapter contributes towards addressing our fourth research question outlined in 1.2.1, concerning the development of effective processes to study resilience strategies, and forms part of our fourth contribution (1.2.2) in representing a technique that can be used to elicit and record resilience strategies. For future researchers seeking to collect and better understand the resilience of individuals, our work here demonstrates the utility and value of adopting diary studies for their investigation, while raising a number of considerations to note (such as the identification of non-resilience items, and the potential prevalence or absence of different types of strategy that may be encountered using such an approach). We have also discussed how this work informed the development of our theory-building activities described in the previous chapter, and how, owing to the data gathered here, we offer a revised and improved categorisation scheme for resilience strategies that itself can be used as a tool when analysing strategies to articulate common themes in terms of different types of strategy, providing a structure and vocabulary that can facilitate further investigation.

Chapter 7: A Framework for the Deconstruction of Compound Strategies

7.1 Chapter Introduction

In previous chapters, we have provided both conceptual discussion and empirical work targeting a variety of resilience strategies. However, as noted in the discussion in Chapter 6, there is still some inherent ambiguity in the foundational scheme we have been using to analyse and understand resilience strategies. The following chapter presents a conceptual framework generated to help us account for and address this ambiguity, and articulate some of the more 'fine-grained' details of strategies.

The chapter opens with a discussion of one of the key remaining challenges that has persisted throughout our efforts to articulate and define the different types of strategies using our categorisation schemes; that some resilience strategies seem to combine multiple 'types' of resilience and/or target multiple threats and challenges. We develop this discussion by introducing the notion of *compound strategies*, and discuss the implications of such a concept. We present a framework for the deconstruction of compound strategies which assists in the analysis of instances of resilience, by considering the underlying mechanisms and motivations that underpin strategies. We close the chapter with a discussion of the outcomes of adopting this new perspective, how this work has led us to reconceptualise the aforementioned categorisation scheme, and how it can guide the future investigation of resilience at an individual-behavioural level.

As in Chapter 5, we would like to explicitly acknowledge a collaborative aspect of this particular strand of work. However, in this case, input from colleagues was more limited, and not integral to the framework proper. We further articulate and explain this aspect of the work in section 7.6 below.

7.2 The Notion of Compound Strategies

The work presented in the previous Chapters has shown that individuals develop and deploy a range of resilience strategies to maintain performance when threats and challenges are encountered or perceived. While much of the work discussed in the literature review serves to evidence this point and explore some of these strategies, investigators wishing to better understand these strategies in-depth approach a relatively immature field, which currently lacks a comprehensive and foundational account of what types of strategies exist. By developing the Furniss, Back and Blandford (2012) categorisation scheme for resilience strategies, we have sought to provide such an account, articulating patterns in observed strategies and thematically grouping these to build a set of broad prototypical categories of resilience strategy that transcend specific domains or contexts.

Our work to date has collected a large number of resilience strategy accounts to broaden the pool of strategies in consideration, and has used this expanded data to develop the categorisation scheme in terms of conceptual coverage and clarity. This has led to the recognition of new categories or types of resilience strategy, while also refining and cementing the language used to define and express these types of strategy. From conducting this work, we have arrived at a more stable and robust scheme than that which proceeded it, as evidenced by multiple rounds of interrater assessment and validation.

From conducting these exercises however, one point has become increasingly clear; while some strategies are relatively simple to understand and label, others have proved inherently more complex and challenging, and have persistently been difficult to accommodate for and characterise, even within our newly developed scheme. The primary reason for this is not because such strategies are not reflected within our scheme, rather that in many cases, strategies seem to contain elements from multiple scheme items. Investigators attempting to apply the scheme are presented with a significant challenge when considering some strategies that seem to, for example, simultaneously incorporate elements of cue creation and

also appropriation, or combine a pre-emptive checking step with a reconfiguration of the nature of a task. Such cases illustrate how the selections of a rater when utilising the scheme are still a somewhat subjective step, open to interpretation in a manner that challenges the utility of the scheme, when complex cases are considered.

Perhaps the most straightforward way to approach this complexity would simply be to re-frame the exercise of applying the scheme, to facilitate the selection of multiple scheme items to describe a single strategy. By adopting such a stance, the scheme in its current and existing state could very likely be applied with increased consistency and stability, and could accommodate for these challenging cases. At the same time, however, to proceed with such an approach would also be to circumvent, and not address, what we have come to realise may very well be a something of a miss-step in our conceptual approach to the investigation of (some, i.e. particularly complex and problematic) resilience strategies.

The observation that in order for our scheme to accommodate some instances of resilience strategy use, we need to simultaneously consider and marry these distinct and intentionally separated scheme items, serves to demonstrate the existence of a more 'fine-grained' unit of analysis. Our work thus far has considered strategies as observable episodes representing a users' behavioural course of action, however in some cases users seemingly combine or 'stack' multiple behaviours or 'sub-strategies', representing different scheme items, into one apparent course of observable action. Given this realisation, we considered that a more promising approach for us may be to consider how these complex cases can be 'unpacked' or deconstructed, in a new approach that could provide greater analytical and explanatory power, potentially yielding new insights into understanding why strategies are enacted, and how they work.

We should at this point re-emphasise an important consideration in this approach, that not all strategies seemingly constitute these complex and entangled cases. Indeed, the majority of strategy accounts we have collected can be accommodated for in our existing version of the categorisation scheme consistently and with relative ease. However, where behavioural episodes are reported that

seemingly incorporate multiple 'strategies within strategies', or span multiple items within our categorisation scheme, we now term these *Compound Strategies.*

Our reconceptualisation of the idea of strategies comprising multiple components led to us draw an analogy with the field of chemistry, in which compounds comprise the combination of multiple elements, hence our use of the term *compound strategies*. By breaking-down these complex cases of resilience strategy use into their constituent parts or elements, and by identifying the elements at play and their various interactions, we intend to better understand the mechanics of compound resilience strategies. To gain such insights would move us towards our ultimate goal of better understanding how and why resilience strategies work, knowledge which could ultimately inform practice and design both within and beyond the field of medical HCI from which this work originated.

In adopting such a perspective, one immediate question arises however; just what are these elements, and what form does this new unit of analysis take? We offer an answer to this in the form of our framework for the deconstruction of compound resilience strategies, described below.

7.3 The Need for a Framework

As discussed, the recognition that some resilience strategies incorporate multiple elements that are simultaneously represented by different items within our categorisation scheme led us to reconsider the nature of these complex cases. As a means to articulating these elements and exploring their nature and the relationships between such elements, we devised a framework to help structure our analysis of these cases. Here, we present a discussion on the development process for devising this framework.

7.3.1 Rationale

As described in 7.2, analysis of examples of resilience strategy use gathered across our work to date led us to reconceptualise the nature of what constitutes some

resilience strategies. Our work to this point had been conducted on the basis of considering strategy accounts themselves to be the fundamental unit of analysis, comprising individual, self-contained episodes of resilience strategy usage as reported. We have, however, moved towards a new account that also conceptualises *compound strategies* to incorporate multiple behavioural and motivational components. In adopting this new approach, the primary challenge that persisted throughout our categorisation scheme work, that of assigning one episode to one category over another, effectively becomes redundant. Reported episodes of compound strategies can simultaneously bear relevance to more than one category, if meaningfully deconstructed into their constituent components.

The following strategy account (captured as part of activities described in 6.4) represents an example of a type of compound strategy that may have presented issues when selected for categorisation, even within our updated and revised 10-item scheme for resilience strategies:

> "When out and about, and needing to take a copy of a receipt or similar, I will take a photo on my mobile phone. As I regularly check my photos, this is quite reliable."

While this case might, upon first inspection, seeming represent a fairly simple or even mundane episode, the example actually features multiple resilient qualities upon closer analysis. By generating an image as a record of the contents of a receipt, one strategy is being applied in terms of the creation of a **new artefact**, which will serve to help record the information more permanently and/or duplicate it to ensure it is more easily available. The improvised use of one's mobile phone camera as a means to generating this digital copy could simultaneously be flagged up as an instance of **appropriation**, given that its primary purpose is not generally taken to be the scanning of documents or paper records.

Similarly, other episodes of resilience as reported within our diary study also serve to illustrate how behavioural strategies that seem relatively simple can feature an interaction between different resilience-related elements:

> "When I use a taxi app (Hailo), it always asks me to review my driver at the end of the journey. I never have time to do this as always carrying lots of bags (hence using a taxi.) so no free hands to give them 5 stars etc. I quit the app by clicking the home button, this ensures that next time I order a cab, I have to review the previous journey first, as it saves the app on the last screen from my previous journey. This acts like a reminder, as otherwise I would forget to review the drivers (and then they pick up less jobs)." (P4)

In this particular case, our participant is demonstrating both the reactive **dynamic adjustment of workload** (effectively moving a subtask from the end of one interaction to the beginning of the next) but is doing so in order to generate a **visual cue**, which will serve as a reminder to bring attention to the fact that the task has yet to be completed.

One interesting notion evident in these cases is that there are seemingly loose dependencies at play between the multiple strategy elements; in a sense, the whole is greater than the sum of its parts. In the first, the creation of the artefact is not easily possible without the functionality of the tool (and were the functionality of the tool not to be appropriated in this way, it would be the 'wrong tool' to facilitate the creation of the copy). In the second case, the reconfiguration of the task sequence (necessitated by the practical circumstance of not being able to easily complete the task there and then) would be prone to a memory slip without the generation of a cue, to serve as a reminder.

Such cases illustrate that there are elements to be considered here that are combined to form effective resilience strategies. This is not representative of every resilience strategy of course, but where it is observed, it becomes less insightful to consider the strategy as an observable and behavioural unit of analysis without first

'unpacking' it to better understand the elements at play. It is the current framework, utilising the 10-item categorisation scheme, that we employ to try and articulate and better understand these underlying elements.

7.3.2 Development and Methodological Approach

If we do consider that compound strategies comprise multiple elements, questions arise concerning what 'types' of element exist. There are perhaps multiple ways in which these could be framed, and our initial premise was in considering there to be *sub-strategies*, or 'strategies within strategies'. With this notion in mind, we considered some example cases of apparent compound strategies in order to determine what insights the adoption of such an approach could yield.

It became clear early on, however, that to merely conceptualise what we finally decided to term 'compound strategies' as 'sub-strategies' ultimately revealed little more about how or why they worked. It was soon deemed necessary to further inspect and more closely analyse these sub-strategies themselves, and further decompose the unit of analysis being investigated. We consulted relevant literature to guide our approach, and specifically we identified that one promising body of existing work would be in *task analysis*, which seeks to investigate how tasks are planned and achieved.

The undertaking of a resilience strategy can be considered to be the undertaking of a form of task. Both comprise goals (and/or subgoals) that are achieved by planning and executing intentional courses of action, forming a behavioural procedure. There exists an established literature on task analysis within HCI that helps to analyse and model generic tasks (i.e. not grounded in specific contexts) by breaking them down into finer units of analysis. Given that our objective seemed highly comparable to this, we reasoned that an analogous approach, and thus analogous apparatus (in terms of frameworks and theory for the decomposing tasks) might serve to benefit and inform our own work.

In what has become foundational work within the field of HCI, Card, Moran and Newell (1983) proposed *GOMS*. This provides a framework for modelling how users conduct tasks and interactions with technology. The approach essentially deconstructs tasks (as observable courses of action), into the sub-components of *goals, operators, methods* and *selection rules*. While GOMS is broadly used as a tool to model the cognitive processes that determine users' actions, the approach equally can be taken as a framework for breaking down complex tasks down into more accessible units of analysis. In so doing, it makes more approachable the aim of better understanding how users realise and execute tasks, and represents a tool we were keen to leverage, given the obvious parallels here with our own scenario.

Utilising the GOMS approach as a structural template (the implications of which, we further discuss in 7.6 below), we sketched a basic conceptual framework that can be used to guide the process of deconstructing and analysing resilience strategies at a more fine-grained level than that previously possible when applying the existing literature specifically on individual's resilience strategies.

An initial draft of our framework for deconstructing resilience strategies was pared-down and the terminology refined. We also considered how the framework could be presented graphically. We discuss these modifications below in the context of our detailed description of the resulting framework.

7.4 The Resulting Framework

Our framework for the deconstruction of resilience strategies, (Figure 21), is loosely based on the format adopted by Card, Moran and Newell in their description of the GOMS framework for the modelling of cognitive processes used in task completion within HCI. While our four key items, *Motivation, Intention, Action, Mechanism* map loosely onto the *Goals, Operators, Methods and Selection Rules* of GOMS, we have adapted these representations to better suit the application of analysis of resilience strategies. Each of these items is discussed in turn below.

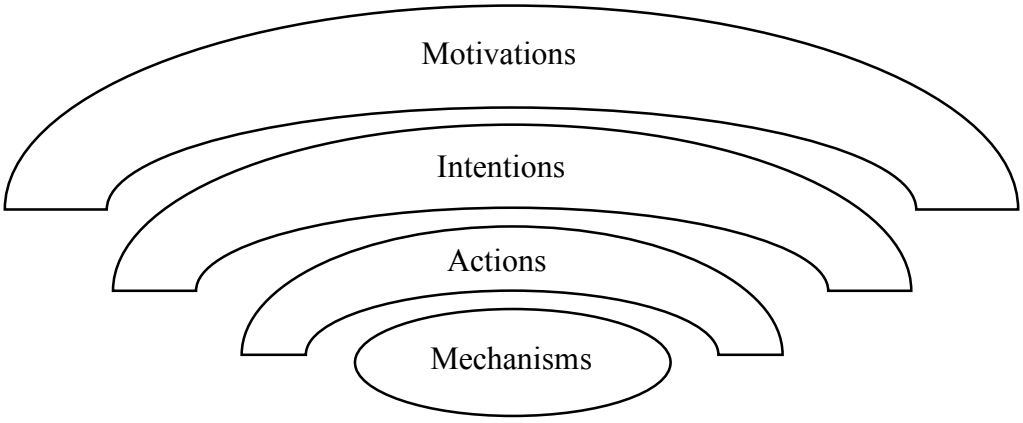


Figure 21: Framework for the Deconstruction of Resilience Strategies

The first item we consider, which consists of the highest-level goals of a strategy, we have termed **Motivations**. These motivations represent a form of framing context or lens, through which to consider the subsequent lower-level goals of the strategy. We considered the goals of resilience strategies at the broadest level to comprise one of two objectives: (i) addressing potential critical errors or frailties (which we conceptualise as 'improving safety' or 'reducing risk'), or (ii) optimising/improving the execution of a task (which we conceptualise as 'improving performance/efficiency'. These high-level goals remain consistent across all manner of tasks and settings and are thus somewhat predetermined within the specification of the framework. It should also be noted that while such a broad framing step may appear superfluous when considering individual strategies (for example, resilience strategy episodes collected during a diary study), this has potential to provide useful structure and even some notion of precedence or priority if multiple strategies are being considered at a 'plant level' (for example, all the strategies deployed by technicians in a control room are being scrutinised).

By contrast, our **Intention** step represents more task-specific subgoals that users/operators would form and comprises the reasons *why* they adopt a strategy. Goals at this level are more tangible than at the motivation level, and are the types of objectives that users deploying a strategy would themselves most likely be able to

articulate (this is because we recognise users may not necessarily identify the broadest level *motivation* for a strategy as we specify above). For example, in a strategy that involves cueing, the intention would generally be to remember the item that is being cued (e.g. 'set a reminder, to remember to collect a train ticket when entering the station').

Crucially, and in a departure from our previous approach to the consideration of strategies, we recognise here that a single strategy episode (as captured or reported within our collection methods) can contain more than one intention- i.e. people can simultaneously want to achieve two or more things by utilising a strategy. Expanding our example above, perhaps the individual in question may wish to incorporate the booking reference information required to collect their ticket, and in such a case their strategy could be said to have two intentions; (i) to provide a timely reminder to eliminate the risk of forgetting to collect their ticket, and (ii) to ensure the required information is available in order to facilitate or enable the task. In such cases, the articulation and disambiguation of such goals could become more challenging even on the part of those utilising strategies, and thus a more fine-grained analysis of an individual's goals (as assisted through their recognition within this framework) can yield enhanced insights, even if investigators will necessarily be required to work from inference or interpretation at times.

The separation and articulation of multiple subgoals is an important new analytical step, as the presence of these in a compound strategy was a point of contention during earlier analysis. In our previous undertakings whereby raters attempted to determine the goal of a strategy, an interpretative step was required to select one of these goals, when each may have been technically relevant and applicable. By recognising the potential existence of multiple intentions in our analytical apparatus, the potentially subjective or ambiguous 'judgement call' of selecting one subgoal over another is no longer required, and the analysis can consider the implications of each in turn.

Actions in our framework represent the concrete and observable behaviours and operations undertaken, in order to achieve intentions. While intentions could be

conceptualised as *why* strategies are developed or deployed, actions describe *how* a strategy is executed. Actions are, like intentions, grounded within the specific context of a given strategy and represent the course of actual and observable action taken, incorporating the steps a user/individual takes and the resources required to achieve a strategy. Continuing our ticket example from above, an example action may be to set an alarm on a mobile phone to act as a cue, or to write down booking information on a piece of scrap paper and put it in one's pocket. For a motivation to be realised or achieved, a corresponding action or set of actions must be planned and enacted as part of the execution of a strategy.

As previously noted, both intentions and actions are formed from the specific and real-world contexts of a given strategy, meaning while their articulation is a useful undertaking in analysis, the extent to which such items are transferable is limited. **Mechanisms** represent a set of prototypical and transferable principles or functions that describe in essence what a strategy consists of, or what 'type' of strategy it is. Our shift in perspective in terms of identifying and considering the notion of compound strategies has led us to reconceptualise the items we previously generated as part of our categorisation scheme, to become a set of mechanisms that can be used within the current framework. For example, the mechanisms at play in the example strategy we are discussing here would be the use of **cueing** (the reminder) and also potentially the creation of a basic cognitive **artefact** (i.e. the noting down of the required information).

In addition to describing these four key items of our framework, it is also important to discuss how these items relate to each other, since this comprises an important aspect of how the framework can be used to analyse resilience strategies. Crucially, the ability to not only deconstruct strategies into their constituent parts, but also investigate the relationships between these aspects of a strategy, represents an important development in terms of how we approach the analysis of resilience strategies, and how further insights can be gained from this more detailed analytical perspective.

While the above framework can be used to analyse any resilience strategy, not all strategies constitute the types of complex, *compound strategies* that originally inspired the creation of the framework. Within the body of strategies we have collected throughout the course of this work (as described in Chapters 4 and 6), many cases represent what we now term to be *simple strategies*; that is to say strategies which comprise only a single motivation, intention, action and mechanism, with an easily traceable one-to-one relationship between each. Where more challenging cases arise however, we note compound strategies can exist in a number of different configurations.

The vast majority of strategies we have encountered and considered address only one over-arching motivation; either the reduction of risk/improvement of safety, or the improvement of efficiency/optimisation of a task or process. In a small number of cases, however, it is possible to ascribe both such motivations to a single strategy episode. However, in such cases there appeared to be a discernible 'primary' and 'secondary' motivation. As mentioned in our definition of intentions, one significant revision of our approach lies in the notion that a single strategy may seek to address more than one sub-goal or intention. Subsequently, multiple actions are equally plausible as a means to achieve multiple intentions.

We also recognise however that, borrowing terminology from database relationships, in addition to a possible 'many-to-many' style relationship (or multiple 'one-to-one' type relationships) between intentions and actions, both a 'one-to-many' and a 'many-to-one' relationship is equally possible. This means that a single strategy may have multiple intentions that are achieved by the same action (continuing the aforementioned ticket example, if the user 'named' an alarm on their phone with the necessary information to enrich the cue with semantic information, that one action could address multiple intentions), or alternatively it is equally possible to have multiple actions used redundantly to reinforce the execution of a single intention (for example a user may write the required information onto the back of their hand, but additionally carry a spare paper record or digital copy in case they wash the information off their hand- multiple actions to achieve a single intention).

If many different types of relationships can exist between potentially multiple intentions or actions, a further logical consequence of this is the possibility for multiple mechanisms to simultaneously be at play. These mechanisms map across to actions, and the variety of possible relationships between intentions and actions is mirrored between actions and mechanisms, with the possibility for many-to-many, one-to-many and many-to-one type relationships existing.

A final note regarding the visual representation of the framework, is that the format selected here to display the four key items is intended to reflect the somewhat hierarchical relationship between the items. The depiction of the items represents how motivations encapsulate intentions, which themselves encapsulate actions and in turn mechanisms. The largest symbol (motivations) also represents the broadest and most high-level aspect of the framework, while mechanisms, the most 'pared-down' and specific aspect of the framework is represented by the smallest symbol. As noted, for any given *compound* strategy, one is likely to encounter multiple items, particularly intentions, actions and mechanisms, which when visualised would therefore reflect more of a 'tree diagram' format.

7.5 Applying the Framework

In the previous section, we used a single hypothetical running example to illustrate the various key items within the framework and how they can be related. Here, we illustrate how the framework can be applied by presenting an account of its usage to support the analysis of the two example compound strategies that were discussed previously in 7.3.1. The first example was:

> "When out and about, and needing to take a copy of a receipt or similar, I will take a photo on my mobile phone. As I regularly check my photos, this is quite reliable"

This strategy represents a relatively unusual case whereby two **motivations** could be said to emerge: the primary motivation of addressing the threat represented by the loss of the information contained within the receipt (MO1) but also potentially a more nuanced secondary motivation of improving performance, by making the information more readily available and thus easy and quick to locate (MO2). With regards to the relevant **intentions** present within the example, the user in this case has an intention of generating a second copy of the information (I1) and also the implicit intention to generate and distribute multiple records of the information across multiple locations since the details contained will at least be present in their paper form and in a digital format on the mobile phone (I2). The observable **action** the user takes is simply to take a copy of the information by utilising the camera on their mobile phone (A1), which addresses both intentions I1 and I2. In terms of **mechanisms**, we identify 3 potential mechanisms (based on the revised version of the categorisation scheme for resilience strategies as our mechanisms list) which are ME1: reinforcing an existing safety barrier (where I2 reduces impact of lost backup), ME2: Managing resource availability (addressing secondary motivation MO2) and ME3: Appropriating a resource (in appropriating the camera functionality of the phone as a data capture tool).

The second example which we will use to demonstrate the application of our framework, again representing a real-world resilience strategy captured during one of our diary studies, reads as follows:

> "When I use a taxi app (Hailo), it always asks me to review my driver at the end of the journey. I never have time to do this as always carrying lots of bags (hence using a taxi), so no free hands to give them 5 stars etc. I quit the app by clicking the home button, this ensures that next time I order a cab, I have to review the previous journey first, as it saves the app on the last screen from previous journey. This acts like a reminder, as otherwise I would forget to review the drivers (and then they pick up less jobs)."

The **motivation** in this example is the recognition that there is a threat that a memory slip will lead to forgetting to complete the rating process, with the aim of overcoming this potential slip (MO1). The **intention** in this case, I1, is to ensure the availability of a visual cue to mitigate the threat presented by the perceived potential memory slip. The user's subsequent **action** is simply to return to the home screen on their device prior to the completion of the final step, in the knowledge that doing so will prompt them upon reopening the application. However, the success of this strategy is reliant equally on the following three **mechanisms**; Pre-completion awareness (ME1) owing to the recognition and targeting of the precompletion-type error, Creating new cues (ME2) in ensuring a visual cue is available to serve as a reminder, and Adjusting a procedure or behaviour (ME3) as the means to achieve ME2.

These examples serve to illustrate how the framework for deconstruction of resilience strategies can be used to inform and structure the analysis of compound strategies, by helping to 'tease-out' and articulate sometimes nuanced aspects and components within a strategy which, nonetheless, represent important contributors to the effectiveness of the strategy. The implications of this work form the subject of the following discussion.

7.6 Discussion

The relative unavailability and immaturity of targeted literature specifically addressing individuals' resilience strategies represented a barrier to structured and consistent analyses. While some strategies had been the subject of analytical discussion, this tended to take the form of highly specialised accounts, grounded within specific contexts. These accounts yielded insights that, while promising, were generally not transferable across different domains and contexts.

Furniss et al.'s (2012) original categorisation scheme, which we contributed to the development of (see Chapter 5), represents an advancement by providing us with an analytical apparatus that supports the articulation of, and reasoning about,

strategies independently of specific tasks and settings. However, this apparatus fell short in supporting the understanding the intricacies of complex resilience strategy examples, which in some cases proved difficult to reconcile with the format of the categorisation scheme upon application. One might assert that the scheme, even in its most recently developed iteration, provided a 'wide' but not 'deep' account of the utilisation of resilience strategies, insofar as it accounted for a very broad range of strategies but provided only limited support for detailed analysis or reasoning. Perhaps because of our still evolving grasp of the nature of strategies, we also encountered challenges regarding the consistency of classifying some strategies, resulting from the level of (relatively unsupported) interpretation required on the part of those applying the scheme.

The unit of work discussed in the current chapter was born out of the notion that some resilience strategies may be more complex than originally recognised, comprising 'compounds' of multiple strategy elements. To explore this notion, we set about considering how we can further deconstruct and unpack resilience strategies, which led to the inception of our framework for the deconstruction of resilience strategies, and also a fundamental reconceptualisation of the role of our categorisation scheme for resilience strategies in appropriating its items as a set of prototypical and transferable 'mechanisms' which underpin strategies. We further identified how strategies can also be considered in terms of the broad motivations which they address, the specific intentions users develop as they identify their goals, and the observable actions which are taken to implement such strategies.

Since we came to reconceptualise the nature of resilience strategies during this unit of work, it is perhaps initially worth returning to the subject of what constitutes a strategy and in what form such strategies are reported. In addition to being the type of complex and broad behavioural phenomenon that would typically represent a challenge to investigate, one noteworthy feature of such strategies is that generally they are reported anecdotally, in natural language and often in an unstructured way. While this may appear a tangential consideration within the context of the current argument, one important implication of this is that the manner

in which strategy accounts are reported is framed by their contributors, who typically do not possess a keen interest or knowledge specifically surrounding resilience.

The subjective and inconsistent way in which strategies are reported potentially goes some way towards explaining why a degree of interpretation has always been required in their analysis. It would appear that sometimes contributors themselves may combine what an investigator would consider to be multiple different strategy aspects into one single account. Similarly, the full significance and details of strategies (for example, implicit subgoals or secondary outcomes) may not be fully articulated. These considerations constituted a persistent challenge during our work with multiple raters (including other investigators with a specific grounding in individual resilience) when assessments were required regarding some of the nuances and intricacies of our collected strategies.

The framework presented here provides a means by which to unpack and deconstruct complex, 'compound' examples of resilience strategies, facilitating structured and detailed analysis of the nature of strategies, and specifically the mechanisms and motivations that underpin them. Where previously we had considered behavioural reports of strategies as somewhat indivisible wholes, we move beyond this view to now consider the components from which they are comprised, and the mechanics of how they function.

When preparing the current framework for presentation and subsequent publication (Day, Furniss and Buchanan, 2015) at the 2015 Resilience Engineering Association (REA) Symposium, one useful illustration of the concept we used was the analogy of *meals and ingredients*. This analogy was introduced by our colleague and co-author for the publication, Dominic Furniss, who suggested the use of this analogy based on prior work by Woolrych et al. (2011). The shift in perspective reflected in the current chapter represents a shift from considering strategy episodes as ingredients to meals: i.e. products that emerge from the synthesis of various ingredients, or in our case, motivational and behavioural components.

While the current framework was generated from a need to deconstruct and analyse 'compound' instances of resilience, our resultant shift in thinking stemming

from this activity can be applicable to the many instances of resilience that we might now refer to as 'simple strategies'. Indeed, while this is not represented in the prior examples of application, the framework can be used to analyse simple strategies where, for example, a user might set a weekly reminder on their smartphone to water their plant. In this case, the **motivation** is to reduce the risk of an error, the **intention** is to set up a regular reminder to assist prospective memory, the **action** would be the setting-up of the reminder and the **mechanism** would simply be cueing. While such a case constitutes a relatively simple and straightforward example, the application of our framework can provide a structure upon which to frame analysis, and by understanding the users' motivation, intention and action, similar strategies in a more substantial pool of strategy accounts could more readily be grouped, compared and contrasted, assisting practitioners and researchers looking to systematically analyse and better understand resilience strategies.

It should be noted however that in many such cases, the greater level of investigative scrutiny afforded by the current framework may not be warranted, owing to the relative simplicity of many of the instances of resilience we have observed. Any future investigators or practitioners wishing to leverage the framework may wish to pause and reflect on whether the added time necessary to consider every case of resilience amongst a large number of cases would be justified in terms of potentially the limited insights yielded. It is for this reason that we still consider the framework predominantly useful in compound cases which more substantially benefit from the approach of disentanglement and deconstruction.

Expanding the discussion conducted above in the previous section on how the framework can be applied to real-world instances of resilience, and the subsequent insights that can be drawn, we posit that the new concept of a variety of potential relationships between components at different hierarchical levels of a resilience strategy offers much new material for consideration and analysis. We see potential in pursuing this notion further, and exploring whether this more fine-grained perspective could result in new approaches for better understanding resilience strategies and patterns of behaviour in greater depth.

We recognise that an argument could be made that the framework introduces a level of detail in its analysis that may seem superfluous, and that some of the distinctions that are drawn during the course of such analyses may be so subtle and nuanced as to appear unnecessary or even arbitrary. For example, regarding the former example case presented in 7.5, the secondary motivation (MO2, which describes the convenience and increased availability of information that is replicated, in addition to MO1 the improved 'safety' of having it backed up) is potentially already inferred and one might interpret it as inconsequential. We would argue that sometimes these subtle and nuanced aspects of strategies can contain inherent unforeseen value. In this particular example, hypothetically one could envisage a scenario in which the secondary motivation routinely improves the efficiency of an individual, for example where the digital reproduction of some information becomes the default way to access it. If a resilience strategy was subsequently formed that addressed MO1 only but did not take MO2 into consideration, while the primary function of the strategy could be said to be intact, the failure to identify the secondary outcome of the strategy could introduce a new frailty or disadvantage in the workflow of the individual. While one of the innate features of user-developed resilience strategies is that they tend to be formulated by the individual concerned and so such weaknesses may be picked up, designers of technical and sociotechnical systems introducing functionality or adapting workflows with resilience in mind may stand to benefit from being mindful of such considerations.

Similarly, during the hypothetical resilience example presented within the description of the four key items in 5.5, one might question the necessity of drawing multiple, different actions to achieve the intentions present here. However, if multiple actions serve to address a single intention, then an element of redundancy is introduced that could strengthen the realisation of a said intention. Alternatively, if one can fold in actions that address simultaneously multiple intentions, for example the use of a rich and semantically enriched cue (a reminder that is both timely and effective, but also contains relevant semantic information), as opposed to a simple cue and a simple cognitive artefact, what results is a more robust strategy. This again

represents (albeit early) discussion in an area which may show promise ultimately in terms of the decisions taken by designers if integrating resilience principles into new or revised systems.

At this point, we acknowledge, however, that this framework and the specification of the mechanisms represent work of a 'first-pass' nature, and would benefit from validation and potentially further expansion, revision or refinement. The 'motivation' component for example, while providing a framing device to situate an episode and elicit reflection on the nature of the threat or opportunity, may bring only limited insight (since we have framed this at a high level, constituting essentially a choice between threats to the success of an outcome, or improvements in efficiency/performance), and in some cases result in increased ambiguity. A further important evaluative consideration is that in its current format, while the framework has been peer-reviewed to some extent (e.g. during its presentation at the aforementioned REA Symposium), to our knowledge the framework has yet to be applied or assessed in any extended capacity by third party researchers at this stage. We would of course welcome others to assess and validate the framework, apply it to their own instances of resilience, and further adapt of refine it where deemed suitable.

A further evaluative consideration which may be posited is that by basing the current framework on GOMS, a historically influential but arguably somewhat limited and high-level framework, a less-rich picture may be obtained than if a more fine-grained analytical approach had been leveraged (for example, *Cognitive Work Analysis* as described by Vicente, 1999). We feel however that GOMS makes for a more suitable candidate for providing a structural analogue owing precisely to its broader nature, which can be seen as a strength when considering the context in which the current framework was formed. Working with data from a wide variety of tasks and settings, many not formalised and often with limited information existing to build a rich picture of the various settings, actors and resources at play (owing particularly to the brevity of strategy accounts considered during our work in 5.4 and collected as described in Chapter 6) limits the suitability of more low-level and

detailed apparatus'. It is worth recognising that the aims of the current thesis are to generate transferable knowledge owing to the relative infancy of targeted work on resilience strategies, however future researchers looking to investigate resilience in more closely scoped and formalised settings may find a 'narrower but deeper' approach leveraging CWA or other such techniques could build a richer picture where the research context and format of data support this.

We would however reiterate that the framework in its current form, as with the categorisation scheme before it, is first and foremost a tool to stimulate discussion, structure analysis and provoke further insight. We would maintain that the framework plays a useful and as yet largely unaddressed role in facilitating the analysis of compound resilience strategies. In providing insight into resilience episodes observable across a broad range of contexts, we suggest this work assists not only analysis of domain-specific existing accounts of resilience, but potentially facilitates transfer of resilience strategy insight across domains. By deconstructing complex strategies and understanding why (motivations) and how (mechanisms) they work, one is in a stronger position to accommodate and manage the implementation of resilience strategies at the 'sharp-end' of interactions with future sociotechnical systems.

7.7 Evaluations and Contributions

As noted in Chapter 5, the amended version of the categorisation scheme for resilience strategies presents us with a foundational account of resilience at an individual level by articulating a set of 'types' of strategy. While this represents a useful conceptual framework with which to frame analyses of resilience strategies, limitations persisted in terms of accounting for complex or compound strategies in which multiple strategies or strategy mechanisms are seemingly combined, to address one or more challenges or threats.

The work described in the current chapter represents a re-framing of the conceptualisation of resilience strategies, and in particular with regards to the types

of compound strategies that were proving problematic to reconcile with our existing apparatus for analysis, the categorisation scheme. The very introduction of this notion of compound strategies represents in itself a useful contribution towards the investigation and analysis of resilience strategies. The implications of this reframing or reconceptualisation, while perhaps yet to be fully explored, could represent at least as significant a step forwards for investigators wishing to better understand how and why strategies work, and move towards the concrete application of resilience principles in technical or sociotechnical systems.

The introduction of our framework represents, to the best of our knowledge, the first attempt at a targeted framework to structure the decomposition of resilience strategies irrespective of their particular contexts or settings. This undertaking allows us to understand not only what types of strategies exist (the primary focus of the categorisation scheme as described in Chapter 5) but to begin to reason about how strategies work, and how they may be strengthened. For example, as illustrated in our discussion surrounding the second example we provided for application in 7.7, we can begin to see why some strategies may be more robust or offer greater redundancy than potential alternative strategies, as a consequence of their compound nature and the dependencies or relationships between the different elements from which such strategies are comprised.

By being able to deconstruct complex cases of resilience strategy use that would previously have proved troublesome to account for with existing analytical apparatus, the framework can be used to guide and structure more detailed analyses, and subsequently yield potential new insights into how and why resilience strategies may be effective or otherwise. In addressing RQ2 (1.2.1) and forming C3 (1.2.2), we ultimately see this new approach not as making the categorisation scheme discussed in Chapter 5 redundant, but rather as representing a complementary approach to enhance insights in terms of depth. Taken in combination with the application of our categorisation scheme, researchers working in the field of resilience have an expanded analytical base with which to specifically target resilience strategies. An approach for potentially combining these is described in the chapter following.

Chapter 8: Study III: A Controlled Study into Resilience Strategies in Task Interleaving

8.1 Chapter Introduction

Previous chapters have described (i) theory-building work we undertook to provide insights into the variety of resilience strategies that exist (Chapters 5 and 7), and (ii) practical work providing the data to inform and support this (Chapters 4 and 6). The work described in this chapter develops in both these regards, taking early steps towards the application of some of our insights, and adopting a complementary new approach to yield further data to support analysis and broaden the work underpinning our contributions to knowledge.

The chapter introduces a second laboratory study in which we sought to investigate a more closely-focused set of resilience strategies, while moving towards a cursory exploration of the potential associations and relationships between specific threats and users' subsequent resilient actions. In so doing, we develop an approach that facilitated a more detailed and deeper understanding of resilience behaviours and strategies, in contrast to the broader and more wide-ranging diary study approach we detailed in Chapter 6.

We provide a discussion of the aims and motivations of this study, describe its conduct, and detail our observations and findings, in terms both of conceptual insights gained and methodological lessons learned. We also discuss how our theory-building work to date helps to inform analysis of these strategies, and how those strategies also serve to support and partially validate our aforementioned categorisation scheme and conceptual framework for the deconstruction of resilience strategies. We close with a forward-looking discussion on the implications of this work and how it could inform future work to operationalise the concept of resilience strategies, which ultimately progresses us towards concrete application in the space of HCI design.

8.2 Study Introduction and Rationale

Returning momentarily to the initial laboratory study conducted as part of this thesis (described in Chapter 4), it could be argued that while the study sought to address ambitious aims, and its adopted approach had its strengths, we began this work with an incomplete picture. This incomplete picture applied both in terms of the types of resilience strategies we studied and identified, and also the practical and methodological approach that we utilised. Subsequent work helped to address the former of these, however while lessons were learned regarding the latter when evaluating the initial study, it is not until the unit of work described in this chapter that we have been in a position to apply them.

Returning to the rationale for deploying a laboratory study method, we sought here to design and conduct a study that would both compliment and expand upon the practical work previously described. One strength from our previous use of diary studies to collect strategy examples was the *variety* of tasks, settings and consequently strategies gathered. While this broad perspective was an intentional choice, a trade-off in this approach is that we did not have sufficient contextual information about many of the collected strategies to analyse them in depth. Another consequence of the breadth and open nature of this approach was that many of the collected strategies extended beyond the domain of HCI, which forms the context of the current PhD. We therefore endeavoured in this final study to collect strategies that were both relevant within the context of HCI, and with sufficient detail to facilitate the type of more in-depth analysis described in the previous Chapter.

One emerging facet of our investigations into resilience strategies raised during our theory-building work, both in Chapters 5 and 7, was the better-articulated relationship between the types of threats and performance issues anticipated, and the compensatory resilience mechanisms that address them. This ‘mapping’ between resilient actions and the nature of the disturbances they resolve, was something we sought to more closely investigate in this final unit of work. In order to achieve this, we opted to return to a controlled study, owing to the possibilities to more closely

constrain extraneous phenomena that this affords. This would in turn enable a more focused approach, when compared with the previous broader studies that instead sought to build an expanded corpus of strategy instances (though at the previously acknowledged cost of providing material less suited to detailed analysis).

In planning this final study, an initial fundamental consideration was in determining what form of study we sought to conduct. Initial ideas centred around the notion of attempting to demonstrate that certain types of threat would trigger certain types of resilient response, in a 'cause and effect' type manner. Adopting such a closely-scoped and rigorous approach, one might argue, could be the most direct route to articulating the sorts of behavioural patterns that could be easily manifested in concrete design guidance. At the same time however, our previous experience in conducting the initial laboratory study highlighted some of the issues and concessions that adopting such an approach would likely entail.

Returning to the initial study, one key insight gained from that early investigation was that attempting to constrain the space of resilient operations available to users had proven to be difficult if not impossible. The very notion of resilience strategies is that users circumvent, adapt to and work around the limitations they encounter, in order to proactively manage their performance in a task. We learned that this applies even within the confines of tightly controlled processes and paradigms. A second insight we noted from our earlier work was that to focus only on part of this picture and work 'against' the resilience strategies of users had the effect of limiting our insights, since we had not initially equipped ourselves to account for and analyse the behaviours and strategies that occurred outside of the closed space of our investigative focus.

We have also learned from our subsequent theory-building work (in particular, in the previous Chapter) that to consider resilience strategies themselves as monolithic units of analysis could itself be regarded as a somewhat reductionist approach. We now recognise that strategies, and indeed components of strategies, interact with multiple threats or goals of users, and indeed with other strategies too. Sometimes, multiple strategies are used in an attempt to address one perceived

threat, while in other instances, one strategy can address multiple threats or challenges. To proceed on the basis of establishing 'one to one' pairings between strategies and challenges or threats would be to neglect one of the key findings of this work to date.

For these reasons, we determined that attempting to study a formalised set of strategies and behaviours in causal relationships and in isolation, would be to fall into some of the same traps we have now identified from our earlier work. We instead decided that this current investigation would therefore assume the form of a laboratory study that would articulate potential *associations* between strategy motivations, mechanisms and threats/challenges, while maintaining the flexibility to accommodate for (and learn from) any unanticipated behaviours and strategies, as opposed to actively trying to 'control out' such phenomena.

Reflecting upon an additional, different lesson learned from our initial study, we faced another challenge in shaping and constructing the task paradigm to be used in this final investigation; with this final study, we determined that task performance would not be a central metric (if used at all), since our focus was on the resilience of users themselves and the nature of the strategies/behaviours observed, in combination with the threats and challenges faced. However, the provision of some form of task would still be necessary in undertaking this in order to elicit resilience, and a notable challenge of the original investigation was in pitching the difficulty of this task, resultant from the nature of the task itself.

One consequence of previously utilising a task which involved a heavy calculation component was that our participants approached the task with a wide range of pre-existing abilities and baseline performance levels, owing to their familiarity and comfort (or lack thereof) with undertaking calculations. These individual differences resulted in a task paradigm which some participants found more demanding than others, and those who were particularly adept with mental arithmetic, for example, approached the task at a significant advantage. Because the task was essentially 'easier' for some participants than others, different threats and challenges were presented to participants with different pre-existing abilities, which

we reason, could alter their need to perform resilient operations, or potentially the types of strategies and behaviours deployed. Learning from this, we determined early on that we would develop a task paradigm that moved away from calculations or any other such activities that we could anticipate may result in inconsistencies in terms of underlying or pre-existing performance. By developing a novel task that, in effect, resulted in a more 'level playing field', we anticipated a more stable and consistent manifestation of users' resilience.

8.3 Study Aims

In the broadest terms, the current study sought to investigate how we can begin to apply the insights provided by earlier work the scheme and framework in chapters 5 and 7, both in terms of methodologically (building upon Study 1 in Chapter 4) and in terms of utilising and evaluating our new theory base (as described in Chapters 5 and 7). In particular, we sought to explore how the underlying motivations and mechanisms of a strategy relate to each other, and to a variety of potential threats that may impact a users' performance.

To achieve this overarching aim, we can consider the more tangible aims and objectives of this work as being threefold:

1. To establish patterns of behaviour and potential associations between the use of strategies or their components, and the threats/challenges faced

The central, primary aim of the current study, and area in which it most fundamentally departed from our previous studies, was in our intention to examine patterns and associations here between strategies and threats or challenges faced. This assists us in better understanding our new conceptual position on resilience strategies, as discussed in the previous chapter. We intend here to investigate the interplay and relationships between strategy mechanisms, motivations, and the threats and challenges they seek to address.

2. To establish and implement an effective approach and task paradigm that would enable the elicitation and detailed analysis of a number of resilience strategies in relation to threat, in a controlled setting

The success of this investigation hinged upon our ability to deliver a task paradigm that would support the collection of strategies in the context of controlled and intentionally-pitched threats, in order to achieve our initial aim. We sought to demonstrate developments to our methodological approach when compared to our initial controlled study, principally in terms of (i) ensuring threats and challenges were stable and consistent (i.e. minimising pre-existing variances in performance levels that had stemmed from our calculation based task) and (ii) ensuring our data gathering approach provided sufficient detail to enable structured analysis and deconstruction (i.e. capturing a richness of data that would facilitate more fine-grained analysis of the nature of resilience strategies).

3. To demonstrate how our advancements in theoretical understanding, in terms of the categorisation scheme and framework for compound strategies, can facilitate and inform analysis, and to validate this newly developed theory-base.

In addition to examining the strategies themselves and considering their relationship to threats, another opportunity afforded by this study was to revisit our categorisation scheme and framework for the deconstruction of compound strategies. The collection of a new set of strategies in this study could serve both to demonstrate the utility and efficacy of our newly developed approaches for analysis, serving in part also to validate them. We would thus utilise both of these main features of our enhanced theory-base to facilitate in our data analysis approach in this final controlled study.

8.4 Study Design and Methodology

In order to explore the nature of the relationship between certain types of threats or challenges and the types of resilience strategies that correspond with them, we again developed a study paradigm requiring multitasking on the part of our participants, with interruptions, the time-limited presentation of values, and subsequent placekeeping errors representing the primary perceived threats to performance. As had been the case in our initial laboratory study, we again saw an opportunity for such a task to incorporate HCI in combination with (simulated) interactive medical devices, two features relevant to the context of the PhD. As before, we modelled our task on 'programming' (entering values into) dummy infusion pumps. In contrast to the initial study however, our multitasking in this case involved simultaneously programming two physical dummy infusion pumps, while monitoring a screen that would display required values for only a limited time window. As previously, the paradigm also incorporated an additional paper-based distractor task to increase the level of simultaneously interleaving between tasks.

The following comprises a more detailed description of our sample, of our rationale in the design of the paradigm, and of the tasks which participants were asked to complete during the course of the study. We then describe the threats or challenges our participants would encounter, and describe anticipated potential patterns as to what types of resilience strategies and behaviours we expected to observe, before closing with an outline of our approach for data analysis.

8.4.1 Participants

A total of 25 participants of varying age, gender and occupation were recruited as an opportunity sample for this study. The sample was a majority student sample, owing to the fact that recruitment was conducted via posters advertising the study placed around the College Building of City, University of London. However, several of the participants were university staff or external visitors.

No prior specialist knowledge or expertise was required by participants, and no exclusion criteria were set (beyond requirements as specified by the school ethics policy regarding vulnerable populations, minors etc.).

To reimburse participants for their time, each participant who completed the study was recompensated to the sum of £20 in the form of an Amazon voucher.

8.4.2 Materials and Apparatus

The task paradigm required the creation and setup of a number of materials and apparatus, both in terms of items that were necessitated by the conduct of the task, and that were made available to assist participants in terms of forming resilience strategies. Starting with paper materials, the following were utilised:

- Information and informed consent sheets
- Training sheet
- Distractor task sheets (further described in 8.4.3. below)
- A4 lined notepads (both for participant and investigator use)
- A selection of '*Post-it*' self-adhesive notes and coloured translucent plastic pagemarker tabs for participant use
- Investigator script for post-task interviews

With regards to technical materials necessary for the conduct of the investigation, the following were utilised:

- 2 x simulated infusion pump devices (*Arduino* powered, featuring number-entry membrane keypad and 7-inch colour screen, tripod-mounted. See left of Figure 22)
- 2 x *Dell Vostro* laptops (serving as 'host' machines to run the software simulation of the infusion pump interface on the physical pump devices)

Figure 22: 'Dummy' Infusion Pump (left) and Simulated Interface (right)

- Simulated software interface for infusion pumps[3] (right, Figure 22, above)
- Tripod-mounted *GoPro* wide-angle camera to record sessions from a concealed location
- Wireless network camera, to capture sessions from an alternative perspective
- Ceiling-mounted digital projector and projection surface
- 2 x computers for investigator use (serving as 'host' machines to run a purpose-built *Microsoft Powerpoint* slide-deck on the aforementioned projector, and record the output from the IP Webcam using *Camtasia Studio*)
- Wireless presenter remote, to progress the above slide-deck

We additionally made use of a concealed control room adjacent to the room where the participant was performing the task, with observations possible through a large two-way mirror. This was where the investigator was situated with the *GoPro* camera, computers and paper materials necessary to administer the task.

In the interests of ethical practice and removing any unnecessary deceptive component, all participants were made aware they were being recorded and monitored, and were aware of the location of the cameras in use. The cameras were concealed merely to reduce potential demand characteristics (i.e. participants behaving differently due to the presence of the camera).

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[3] Developed by, and used with the permission of Patrick Oladimeji. Available at http://www.cs.swan.ac.uk/~cspo/simulations/prototype/

8.4.3 Task Paradigm and Procedure

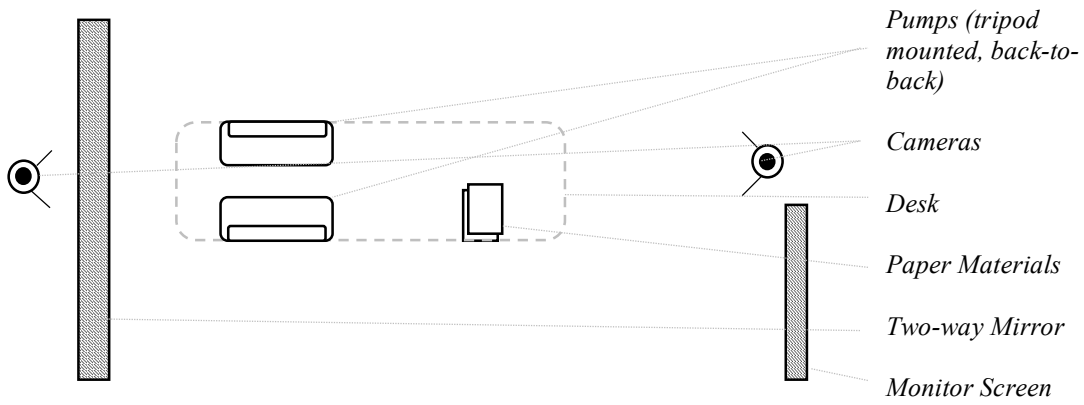


Figure 23: Physical Layout of Study

As with the task we administered in our previous controlled study (described in Chapter 4), we again modelled the task paradigm in this investigation on that of setting up medications to be administered intravenously. Our reasoning remained much the same; that such a task reflects a real-world scenario that is both pertinent to the thesis themes of HCI and medical devices, and can represent a challenging undertaking owing to a number of potential inherent threats and complexities. In a departure from the previous task however, the task we designed here did *not* require a calculation component, and we instead directed our focus towards the challenges presented by interruptions, working memory/cognitive load, and place-keeping.

The primary task required participants to observe a large projected screen (the 'Monitor Screen'), upon which sets of numerical values would periodically appear. Participants were then asked to enter the supplied values into one of two simulated infusion pump devices. These devices (identical in form and function) took the form of physical 'dummy' pumps, mounted on tripods so as to be at a comfortable height to operate, and consisted of a 7-inch LCD screen and membrane-type keypad upon which to enter values, arranged in a white plastic enclosure.

Each pump was connected to a host laptop computer, running a simulated infusion pump interface, with the screen contents duplicated upon both the pump screen and laptop screen. The host laptops were placed facing the two-way mirror, enabling the experimenter and GoPro camera to view screen contents in real time from the adjacent control room, but were oriented away from the participants (it was intended that participants were not able to view the laptop screens, however it was possible to catch sight of a reflection of the screen contents in the mirror, which was an unfortunate consequence of physical constraints in the setup of our equipment).

Upon entering and confirming these values, participants would then allow the simulated infusion pumps to process their entered values, which took a predetermined length of time (varying from 24 seconds up to 4 minutes and 30 seconds, according to the values entered), simulating what would be the delivery of medication in a comparable real-world scenario. Naturally, in real world settings, the delivery of medications would take much longer, however we designed for shorter durations to ensure the task could be conducted within a reasonable timeframe.

Regarding the values presented on the monitor screen, each participant was provided with the same sequence of screens, which contained a total of 14 'sets' of values (2 of which were only used for a training session, leaving 12 sets for the study session proper). These sets of values each contained the following 3 items: *Pump Number* (either 1 or 2, indicating which pump to program), *Rate* (replicating the rate of delivery for a medication) and *VTBI* ('Volume To Be Infused'; the volume of medication). When each new set was presented on the monitor screen, the screen was designed to flash white and a short audible ringing tone would sound, providing both a visual and auditory cue signalling the arrival of a new set of values. Each set of values was only visible on the monitor screen for a duration of 25 seconds, after which the screen would fade to black, presenting only a limited window of time in which participants could view each set. Participants were made aware of this limited time window during the instruction session, and this was demonstrated in the training exercise.

The points at which a new set of values appeared on the monitor screen were controlled by the investigator, with a mixture of 'points of interruption' (i.e. each participant was interrupted at various points during the task, including when they were moving from one pump to another, during the entering of a previously displayed set of numbers, and during their progression through a secondary distractor task described below). In terms of technical setup, the values presented on the monitor screen took the form of a *Microsoft Powerpoint* slide-deck, running on a concealed computer in the adjacent observation room, with the slideshow being projected onto a whiteboard within the study room via a ceiling-mounted DLP projector. The investigator used a wireless presentation remote to progress through the slide-deck and present each new set of values.

During periods when waiting for the simulated pumps to finish running, participants were also asked to undertake a secondary distractor task. This task simply required participants to look over pre-prepared tables containing large grids of numbers, and copy all the values that contained a decimal point onto a separately provided pad of paper. This task was, by design, a task that was both attentional and working-memory focused, however that did not require calculation (as had been included in our initial controlled study described in Chapter 4). The task was included both to provide participants with an activity during 'downtime' from the primary task, but also to add complexity and additional cognitive load. The numbers featured on the distractor task were also similar in nature to the values presented on the monitor screen, an intentional design consideration to introduce potential 'crossmodal' complexity (that is to say, the complexity of simultaneously undertaking two tasks featuring numerical values was deemed to be greater than if we had chosen a completely unrelated distractor task).

Given the complexity and unfamiliar format of the task, we incorporated a training session into the study. Upon reading the study information sheet and signing the consent form, participants were provided with an instruction sheet and guided through the process of both tasks by the investigator. The training session involved the demonstration of how to enter values into the simulated infusion pump devices,

followed by the opportunity for each participant to do so in the presence of the investigator, inputting two sets of values that were presented on the monitor screen as they would appear in the study session. Participants were also given the opportunity to repeat the training paradigm if they did not feel comfortable to proceed upon completion of the initial two sets. To facilitate participants' progression through the task, a number of paper Post-it notes and plastic pagemarking tabs, pens and a pad of paper were left at their disposal, with participants being notified that they were available for use if required. However, participants were not explicitly instructed or encouraged to use them. The selection of these materials was based on their ready availability or commonplace-nature in real world situations, and therefore participants' likely familiarity with them. The investigator ensured any questions had been answered and that participants were confident in their ability to control the task prior to leaving the room and commencing the task session from the adjacent observation room. Finally, upon completion of the task, participants were also asked to reflect upon the task, their performance, and the resilience strategies they utilised in a brief, semi-structured interview with the investigator.

With regards to data collection, the progression of participants through the task and their subsequent resilience strategies were monitored in real time by the investigator from the adjacent observation room. These observations were accompanied by concurrent notetaking on a prepared record sheet for each participant (an example of which is included in the paper materials used for this study, contained in Appendix E). To supplement and facilitate later analysis, the full duration of each session was video recorded by two cameras. The first camera captured the study from the perspective of the investigator in the adjacent observation room (which additionally captured the mirrored screens of the simulated infusion pumps from the host laptops), while the second camera was placed inside the room to provide an additional perspective and clearer view of the participants' physical interactions with the pumps, movements around the room, and completion of the distractor task. Audio was transmitted from a microphone in the study room to

a computer speaker in the control room, and recorded using the integrated microphone of the GoPro camera inside the control room. These cameras were also used to record the post-session interviews, to supplement the concurrent notetaking conducted by the investigator during these interviews.

A final source of data from the task was the collection of all paper materials for each participant, including any used Post-it notes or notations on the pad of paper provided, in addition to the paper materials used in the secondary distractor task.

To provide an illustrative overview of the sequence of operations involved in the task, we provide a summary diagram below. Note however that the following represents a generic summary only, as variables in each individual case (such as the time a participant took to program a pump, the point at which they opt to direct their attention to the secondary task, and consequently, the precise points at which they were interrupted by the arrival of new values) mean that the sequence of specific and individual operations varied from participant to participant.

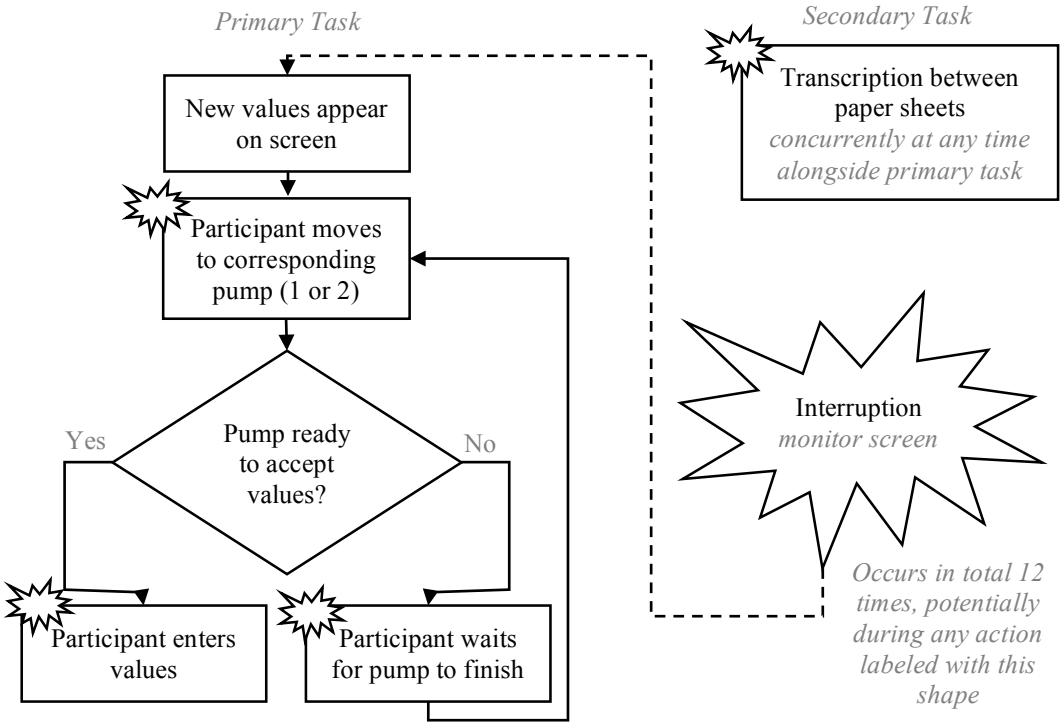


Figure 24. Generic Task Paradigm Overview

8.4.4 Potential Threat-Strategy Associations

As described previously in 8.3, the current study aimed not only to record and evaluate the strategies that emerged during the task, but to move towards establishing preliminary predictive power in terms of potential associations between the type of threat presented and the subsequent strategies that would be elicited. Based on our existing work to date, we felt that we could form early estimations regarding how certain types of strategy may be more prevalent based on the design of our task and the anticipated challenges it presented. While our initial two studies provide early indications as to potential patterns, we recognise that further work would be required to inform rigid or specific predictions at this stage, however as an exercise in testing this notion of threat-to-strategy associations, we established several early estimations as to the types of strategies we anticipated encountering.

A key threat to the successful completion of the task was the potential for values appearing on the monitor screen to be lost before they could be entered into the pumps, given the imposed 25 second limitation on the visual presentation of the values. We anticipated such a threat may be addressed primarily by the creation of artefacts to record values as they appeared (thus easing what would otherwise be a significant burden on working memory). This was informed by our observations of people creating artefacts to support working memory, as noted across multiple instances from the entries gathered during the diary study described in Chapter 6. While we anticipated observing participants recording values onto Post-it notes or the paper pad made available to them, we did not make any specific predictions about the manner in which different participants may accomplish this (for example, whether participants would record all such numbers as they appeared versus only a selection of them, and whether they would create separate records for each value, for each pump, or record all the information on a single page/note). We were interested to observe any variations between the specific strategies participants would develop in this regard, the prevalence of these and if there were consistent recurring cases or significant individual differences.

Another key challenge our participants faced was *placekeeping* or progress-tracking and potential task-resumption errors upon interrupted operations. The potential for such errors arose not only in the resumption of pump interactions post-interruption, but also in terms of maintaining awareness of the completion status of values if recorded by participants (i.e. placekeeping on any participant-generated artefacts), and also in terms of participants' completion of the secondary distractor task (which would be interrupted by the primary task). We anticipated resultant strategies may include the timely and momentary deferral of interruptions to complete subtasks (i.e. completing the entry of values and beginning an 'infusion' prior to attending to new values on the monitor screen) and possible cue or artefact creation to serve as reminders of progression through pump programming (e.g. noting the previous or next step in the sequence, which would vary based on point of interruption, to be checked upon resumption). This was based on our observation of both of these strategies occurring in the presence of an analogous threat during our initial controlled study described in Chapter 4. In terms of tracking entered values versus those still to be entered, we anticipated potentially observing the discarding or crossing-through of sets already entered into the pumps to ensure no unintended repetitions were made. With regards to the secondary task, we also anticipated some form of progress-tracking strategy by marking the paper sheets with cues to denote progress, however the specific format of any such cue creation was not predicted.

Finally, the physical arrangement of items in the study space was deliberately designed so as to not enable concurrent monitoring of both pumps. We therefore noted an opportunity for participants to improve task workflow by reconfiguring the layout of the apparatus within the task. We anticipated participants may seize the opportunity to optimise performance by repositioning the pumps to both be observable from one location, a strategy that would enhance monitoring (to check the progress of 'infusions' and whether a next set of values could be entered) without having to repeatedly move between both pumps. We additionally noted participants may 'move' the paper materials that formed the secondary or distractor task, considering that it consisted only of a couple of sheets of printed paper, and blank

Threat or Challenge	*Anticipated Resilience Response*
Failure to recall values presented on the monitor screen, after they have 'timed-out' and are no longer available	- Creation of artefacts to record and retain incoming values
Failure to resume primary task (entering pump values) in the correct place following attending to an interruption	- Use of cues or adding annotation to above artefacts to support placekeeping and task resumption - Discarding entered values to ensure they are not erroneously re-entered - Deferral of interruptions to complete current programming (number entry) step
Failure to resume secondary task (transcribing values on paper) in the correct place following attending to an interruption	- Creation of cues or artefacts on secondary task paper sheets, to assist placekeeping - Deferral of interruptions to complete current step, and resume the task from a more meaningful place (i.e. subtask boundary)
Inability to concurrently monitor the status/progress of both pumps simultaneously, and when completing secondary task	- Reorganising the physical layout of the task, i.e. repositioning apparatus

Table 7: Summary of Anticipated Resilience Responses

pad of paper for recording, which could be positioned by one of the pumps and therefore reduce the time spent physically moving between locations. These actions represent a conceptually analogous response to a diary entry we encountered and outlined in Chapter 6, whereby a user reported repositioning software toolbars in an onscreen interface to optimise the availability of frequently used resources.

As stated, the anticipated responses presented in Table 7 were not generated with the intention of constituting formal hypotheses, rather as a preliminary exercise towards exploring potential threat-strategy associations. Moreover, while they represent what we perceived to be the most prevalent likely types of strategy and behaviour that we would observe, our goal was not to exhaustively predict *all* resilience strategies that might occur, and we were mindful that other types of strategy would likely emerge that are not discussed here.

8.4.5 Data Analysis Approach

The current investigation sought to return to the practical format of a controlled study, in order to explore a collection of resilience strategies and how these may conform to expectations, based on the threats and challenges presented to our participants. In contrast with our second study (presented in Chapter 6), the current study therefore aimed to analyse a reduced breadth of strategies, however in greater depth.

Upon completion of data gathering, our first task was to identify and record the resilience strategies encountered during the conduct of the study. Many cases had been identified at the time of testing, noted concurrently during both real-time observation, and our post-task discussions with each of the participants. To systematically identify all observable strategies however, the video recordings from both cameras were viewed retrospectively by the experimenter, in combination with the existing notes, and paper materials used by each participant. From this, we generated a transcribed list of each resilience strategy or behaiviour that we could identify from the data, for each participant. Given that the paradigm and threats presented were recursive in nature and the frequency of strategies for each individual participant was not an aim of this investigation, we opted only to transcribe each observed strategy once per participant (e.g. where a participant wrote on a Post-it note 12 times, we transcribed such a case once, rather than as 12 strategies).

Owing to the controlled paradigm we used here, we anticipated (and indeed encountered) considerable conceptual overlapping between many of the strategies collected during this exercise. This should come as no surprise; faced with the same threats within the same conditions, many of our participants opted to utilise the same (or conceptually similar) resilience responses. A first step in our data analysis was therefore to identify such patterns in the form of common groupings, in order to distil our volume of strategies into a set of representative groupings or codes. This process was primarily inductive and data-driven in nature, however include a theory-driven component in that we used our 10-item categorisation scheme to help identify

and articulate these conceptually overlapping groupings, by assigning a category of best fit to each of our transcribed strategies. The term 'best fit' here reflects our reconceptualisation of the application of the scheme as discussed in Chapter 7, and where more than one category item appeared appropriate, we also assigned secondary applicable categories, an undertaking which also served to identify compound strategies. Regarding these cases, we flagged and selection based on perceived interest and complexity, and proceed later to analyse these in more detail with the assistance of our framework for the deconstruction of compound strategies.

To structure the process of deriving groupings, we again leveraged the approach of *thematic analysis* as described by Braun and Clarke (2006), which had proved a useful framework for facilitating data analysis in our previous study. In this case however, we followed a more lightly adapted process, conducting exercises that are more directly analogous to the six-stage process Braun and Clarke describe. The exercise of reviewing video footage and transcribing strategies while cross-referencing these with our notes and participants' paper materials constituted stage one, 'Familiarizing yourself with your data' as described by Braun and Clarke. Consulting these transcriptions together with the supplementary data (i.e. notes and paper materials gathered), and common patterns in terms of category selections, we were able to identify interesting and reoccurring features of the data to generate our strategy groupings, which become analogous to the codes described as stage two.

While these groupings constituted a somewhat abstracted representation of our data, they were still low-level in nature, consisting of summarised prototypical descriptions of the strategies we observed. Upon generating these groupings, it became possible to in turn group these into conceptually comparable collections, a step which represented the third stage described by Braun and Clarke, 'searching for themes'. An iterative process of revising these themes, guided again by the prevailing similarities and differences extracted and articulated during our application of the 10-item categorisation scheme, represented stages four ('reviewing themes') and subsequently five ('defining and naming' themes). Stage six of Braun

and Clarke's process consists of 'producing the report', an activity we complete in the following presentation and discussion of our findings.

8.5 Findings

We present our findings here in two sections; an initial overview describing the variety and prevalence of strategies, followed by a more detailed discussion exploring each of the strategy groupings and themes, and considering each with regards to our anticipated potential associations between threat-strategy, and the application of our newly developed theory-base (in the form of the 10-item categorisation scheme, and framework for deconstructing compound strategies).

8.5.1 Frequency and Prevalence of Strategies

Across all 25 participants, the total number of recorded resilience strategy instances identified was 94, with participants displaying a mean average of 3.76 (*SD=1.51*) strategies each, ranging from a minimum of 1 strategy to a maximum of 7 strategies observed per participant. These values represent the number of *different strategies* noted, as opposed to the frequency of strategy reoccurrence per participant. The full list of resilience strategies is presented, along with their corresponding codes/groupings and themes, in Appendix F.

As described previously in our data analysis approach (8.4.5), we conducted a thematic analysis supported by our 10-item categorisation scheme, first identifying common codes which we used to collate the 94 instances of strategy use into conceptually overlapping or similar groupings. We identified a total of 17 such groupings, reported in table 8 which represent a summarised account of our wider strategy instances.

Abstracting these groupings into broader themes, we identified a total of 6 high-level resilience concepts, which we use to structure our codes/groupings in Table 8 (denoted in *italics*). While the table serves to summarise this data, we

Theme and Code/Strategy Grouping	*No. of Instances*
Recording or Retaining values	
Recording onto Post-it notes	16
Recording as a structured list	4
Verbally rehearsing values to assist retention	11
Progress Tracking	
Marking the secondary task sheet	10
Using finger as placeholder	3
Using pen as placeholder	1
Using plastic tab as placeholder	2
Using paper to occlude completed values	1
Restructuring Task Sequence	
Deferral of interruptions	16
Reordering sequence of secondary task	1
Adapting Physical Task Layout	
Moving the pumps	1
Moving the secondary task sheets	9
Use of reflection for concurrently monitoring pumps	1
Checking	
Post-hoc check of secondary task	10
Redoing task after suspected error	1
Organising and Optimising Information	
Writing additional supplementary instructions	2
Organisation or structuring of secondary task list	5

Table 8: Prevalence of Observed Resilience Strategies

present a more extended discussion of each item in the next section, making reference both to our revised 10-item categorisation scheme for resilience strategies, and our framework for the notion of deconstructing compound resilience strategies.

Each strategy instance was also considered individually within the context of the work described in the previous chapter, with a view to identifying and further exploring any available compound strategies. Adopting this approach, we identified a total of 34 compound strategies out of our total of 94 strategies, representing 36.17% of our full set of strategies. We further discuss a selection of these

compound strategies in the section following, along with an exploration of how the observed strategies and groupings correspond with the patterns outlined in 8.4.4.

8.5.2 A Closer Examination of Strategies

While it would be impractical to present or discuss each of the 94 individual instances we observed, we present here a commentary on the 6 broader themes, and 17 strategy groupings that encompass our full dataset (available in Appendix F).

8.5.2.1 Recording or Retaining Values

As previously discussed, a significant challenge intentionally designed into the task paradigm was the limited window of time (25 seconds) for participants to be able to record new values once they appeared on the monitor screen. We therefore predicted, and indeed observed, a number of strategies aimed at recording or retaining this information. We grouped these into the following codes.

Recording onto Post-it notes

A total of 16 participants made use of the Post-it notes provided in order to record monitor screen values. Within our 10-item categorisation scheme, this would primarily represent the *creation of artefacts*, owing to the creation of not merely simple place-keeping reminders (i.e. cues) but informational artefacts that contain the data required for task completion (i.e. the values presented on the monitor screen). While this may initially appear a relatively straightforward strategy, we note that a wide variety of different approaches were displayed within this grouping.

Some of our participants, for example, recorded each set of values on its own Post-it note (see *top left* of Figure 25), while others preferred to write all values onto a single note (*top centre* of Figure 25). As predicted, some participants also tracked progress on these notes by striking through completed items (again, *top centre* of Figure 25) while others formed a pile of discarded notes once actioned (*top left* of Figure 25) and others still formed no such strategy for tracking progress, instead

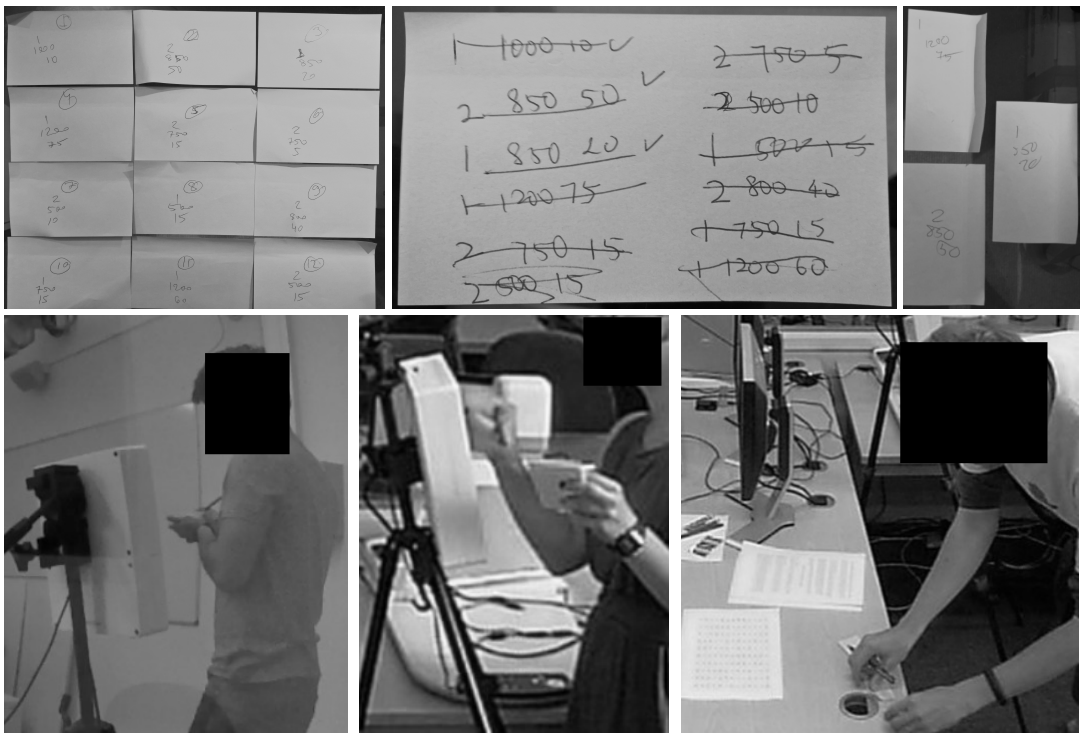


Figure 25. Varying Approaches for the Use of Post-It Notes

relying on their memory of which values had been entered (a behaviour that was easier for several of our participants who, rather than recording all values, only recorded a handful as and when they felt it necessary; see *right* of Figure 25).

In another example of the variety of different strategies used here, some of our participants opted to keep the pad of notes in one centralised location (*lower right* Figure 25), while others took advantage of the smaller size of the pad of notes, taking it with them as they moved between pumps (*lower left* of Figure 25). A further approach some participants used was to attach their annotated notes directly onto the infusion pumps (*lower centre* Figure 25).

These variations in the use of Post-it notes may appear nuanced and even inconsequential, however even seemingly such minor differences can have potential implications. By considering each of the 16 instances of this grouping in the context of our categorisation scheme, we identified that the vast majority (14 out of the 16) represented some form of compound, as the recording of values was supplemented

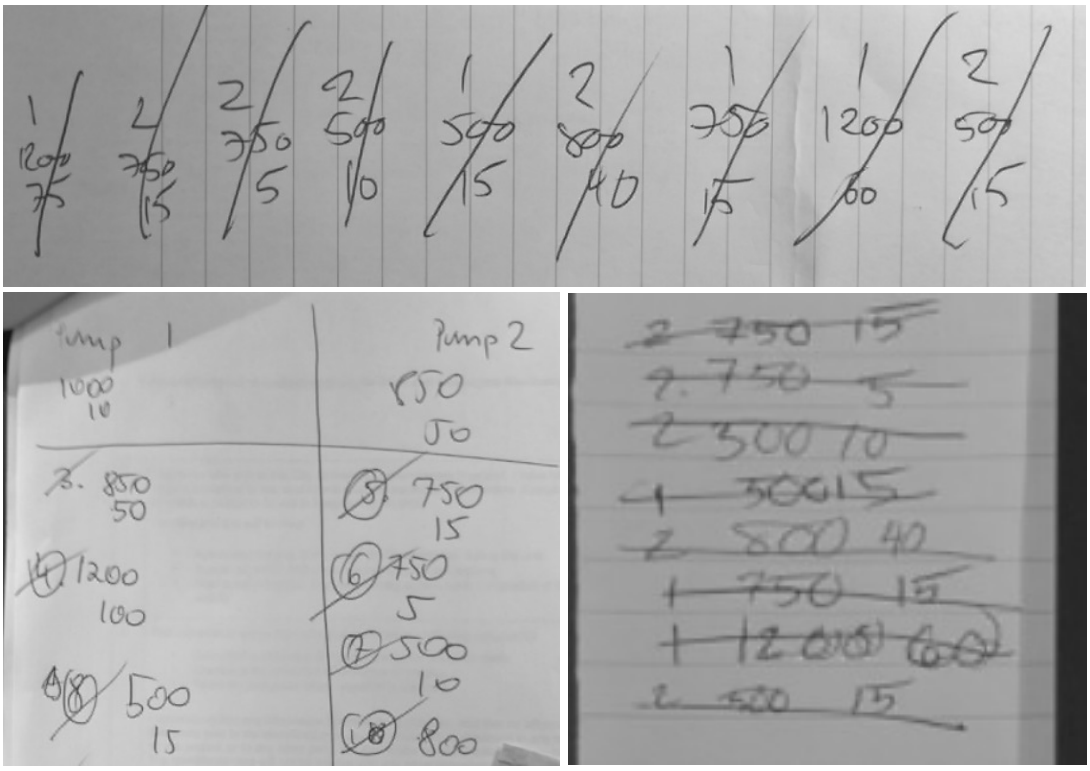


Figure 26. Varying Approaches for the Use of Structured Lists

with some form of additional organising or placekeeping function. In the discussion below (8.6.1) we apply our framework for the deconstruction of compound strategies to investigate some such examples more closely.

Recording as a structured list

A total of 4 participants opted to record values using lists composed on paper as opposed to Post-it notes. Again, this was primarily considered as the creation of new *artefacts* within the scope of our 10-item categorisation scheme, owing to the semantically rich nature of the content contained within these lists in contrast to the 'place-marker' functionality of cue composition. In each of the above cases however, we can see that cues in the form of 'strike-throughs' have additionally been incorporated into these lists as a means to track progress and assist with place-keeping. Such cases could again be conceptualised as compound strategies, simultaneously incorporating multiple concepts as described in our 10-item scheme.

By both representing the creation of an artefact to retain the monitor screen values, as well as incorporating cueing to assist with progress-tracking, these strategies again demonstrate that two of our predicted strategies were observed.

Verbally rehearsing values to assist retention

Verbal rehearsal to assist working memory was observed in a total of 11 cases, thus constituting a highly prevalent manifestation of resilience despite not being represented within our anticipated patterns. In hindsight, given the considerable working memory demands of our task and the fact that this strategy was observed in our previous controlled study, its observation is not surprising. During the task, this took the form of verbally rehearsing the values that appeared on the monitor screen to retain them in the phonological loop as part of working memory (Norman, 1969), generally while moving between or interacting with the infusion pumps. Owing to the 'intention' of this strategy being the retention of information, during our thematic analysis this strategy was therefore considered conceptually analogous to the retention of information on Post-it notes or lists, despite representing a notably different behavioural manifestation. None of the examples of verbal rehearsal were considered to be compound strategies, with all falling under the 10-item categorisation scheme item of *adjusting a procedure or behaviour*, owing to the behavioural adjustment quality of the strategy.

As has been previously discussed in the thesis (4.5, 5.6) verbal rehearsal could be said to represent less of a 'strategy' and more of a 'behaviour', owing to the fact it is often (though by no means exclusively) subconscious and unintentional. In follow-up questioning with some of our participants, we indeed noted in some cases participants were unaware of this, while in others, participants were mindful and conscious of uttering values to retain them in memory. As previously described, while the extent to which this phenomenon warrants investigation within the context of resilience strategies remains a matter of some interpretation, our position is that it remains an observable behavioural manifestation of resilience, and therefore falls under the scope of this work.

8.5.2.2 Progress Tracking

While a number of strategies as outlined above incorporated aspects of tracking progress, the concept of placekeeping formed only elements within compound strategies, and the creation of artefacts to record information was considered not only as the primary defining characteristic of these cases, but it was indeed a prerequisite to any tracking of progress.

In contrast, the cases described here represent attempts primarily to track progress, using cues to support task resumption in the secondary task upon entering values into an infusion pump. This inherent interleaving challenge was again designed into our task paradigm, and strategies involving the use of cues to support placekeeping again represents one of the expected patterns described in 8.4.4.

Marking the secondary task sheet

We observed a total of 10 instances whereby participants marked the secondary task sheets as a way of supporting progress tracking and to assist with task resumption, again conforming to our anticipated patterns. All 10 cases were considered primarily to represent *Creating new cues* when consulting our 10-item categorisation scheme, however interestingly, in 5 of these cases we additionally identified aspects of *Separating task items* indicating that half of these cases incorporated a compound aspect. This reflects the observation that in some cases, participants would make minimal markings to the sheets to denote only where an interruption had occurred (for example, *left* in Figure 27) while other participants more comprehensively marked the sheet, separating the task items (in this case, values featuring a decimal point) from the remaining items, with additional cues to track progress (as shown in the example on the right of Figure 27.

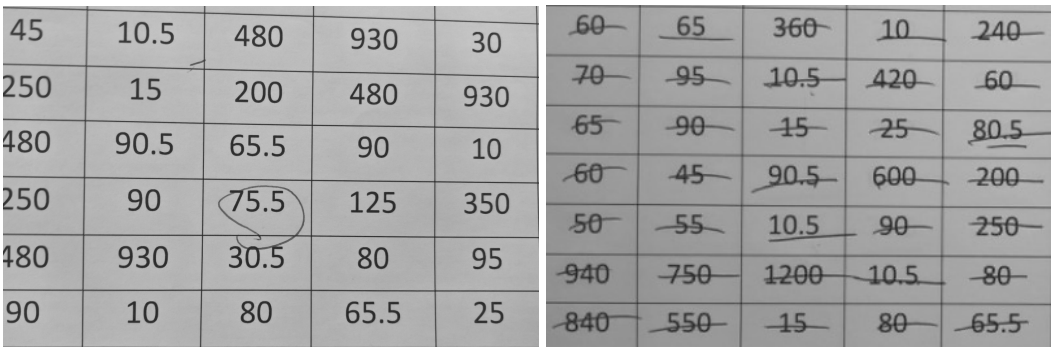


Figure 27. Varying Approaches for Marking the Secondary Task Sheet

As previously discussed in the case of Post-it notes, while the distinction between these different manifestations of the strategy may appear minimal, even these subtle differences may be of consequence. The strategy of the left of Figure 27 for example does serve to assist with task resumption but could be considered as less robust than the strategy displayed on the right, which would facilitate a quicker completion owing to the added disambiguation between the task items of interest and the remaining items.

Using finger as placeholder

In 3 cases, we observed participants using their finger as a temporary placeholder during their conduct of the secondary task, at moments when their attention was drawn either to one of the pumps (i.e. to check whether it had completed processing a set of values) or to the monitor screen. We conceptualised all 3 cases as representing simple *cueing* actions, with no discernible compound quality.

In a similar manner in which verbal rehearsal may be considered as more of a behaviour than a conscious or intentional strategy, one might also consider this manifestation of cueing as more behaviour than strategy. As is the case with verbal rehearsal however, we still consider such observable and inherently resilient behavioural phenomena to be within scope of the current investigation, if they perhaps warrant limited further or more detailed analysis.

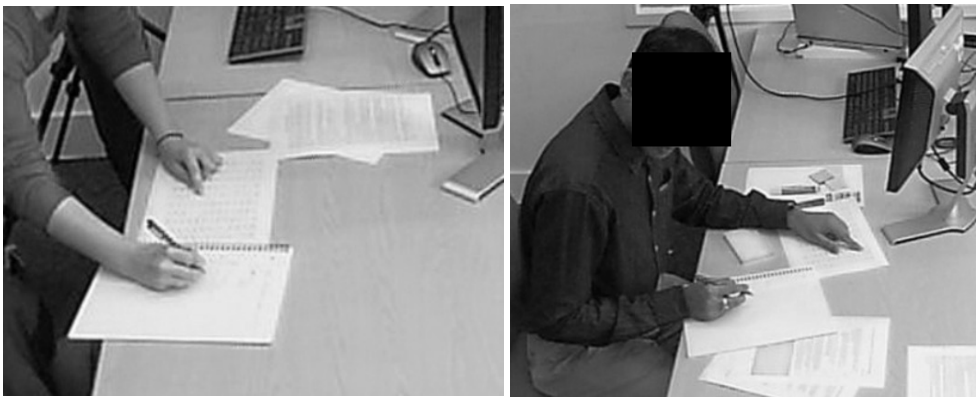


Figure 28. Finger Placement for Progress Tracking

Using pen as placeholder

One participant (Figure 29, above) was observed positioning a pen upon the secondary task sheet as a deliberate place-keeping aide, prior to entering a set of values into one of the pumps. This again represents a strategy we conceptualised as cue creation, as it served a reminder function to support task resumption upon interruption. While this strategy was not predicted directly, it serves as a further example of the broader theme of cueing as a means to track progress and manage interruptions, an anticipated resilience response as outlined previously in 8.4.4.

While in the initial instructions all participants were told that they could write on any of the materials in front of them, post-study probing revealed the participant in question did not realise they were permitted to write on the printed secondary task materials. This misunderstanding likely explains the use of this unique strategy, which is analogous to the other progress tracking strategies, however appears both more time-consuming to initiate, as well as potentially more frail (owing to the possibility that the cue could accidentally be physically moved with relative ease).

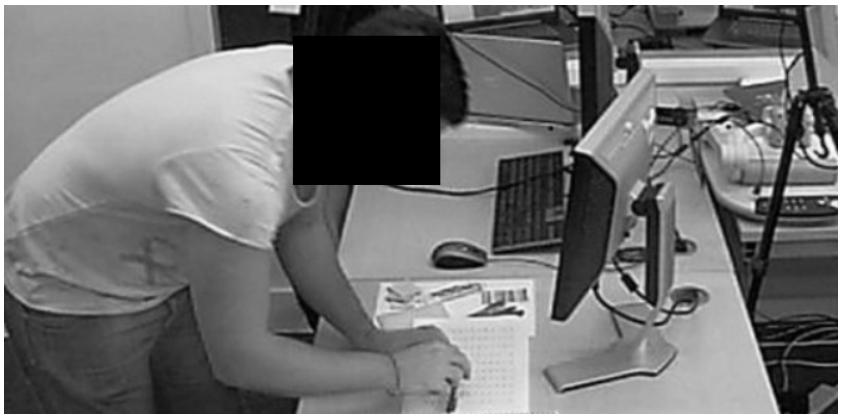


Figure 29. Placement of Pen for Progress Tracking

Using plastic tab as placeholder

Two of our participants opted to make use of the plastic 'page marker' tabs that had been left along with the Post-it notes as an available resource. In both cases, the participants used these as cues to assist placekeeping as they completed the secondary task, however implemented slight variations in usage. One participant (P10) placed a tab on the individual value they were working on upon an interruption, whereas the other participant instead used the tab to mark the row of values they were currently addressing (P19), moving the tab with each new row rather than only marking the specific point of interruption. In the latter case, the participant clarified upon debriefing that they felt this approach provided sufficient support since they could consult their list to determine the exact previous value transcribed, thus the tab was used more to disambiguate rows (i.e. as a means to direct attention) than to directly support working memory.

We would classify both cases as representing examples of cueing, owing to the creation of placeholders to support memory and direct attention, both of which are features of the *creating new cues* item as expressed in our 10-item scheme.

Figure 30. Use of Occlusion for Progress Tracking

Using paper to occlude completed values

One of our participants (P1, Figure 30) displayed a strategy to assist with placekeeping that involved deliberately using a sheet of paper to occlude the portion of the secondary task list forward of that which they had already attended to. In so doing, the participant formed an improvised cue of sorts, to assist with tracking progress upon resuming from an interruption. We considered that the resulting strategy represented a compound, combining *cueing* to support working memory by directing attention, with an additional *appropriation* quality owing to the innovative use of the task sheet as an improvised resource to facilitate the strategy.

8.5.2.3 Restructuring Task Sequence

We derived the theme of restructuring task sequence form a pair of strategy groupings that involved dynamically adjusting the order of subtask steps, be it through deferring interruptions (which had the effect of proceeding through tasks in a more 'organised' manner) or in one case, rearranging the nature of the secondary task to fundamentally adapt and re-order its structure. Strategies under this theme were comparable to some of the strategies we observed in our initial controlled study and, we would postulate, represent a way to potentially both optimise efficiency and mitigate the threat presented by interruption during an interleaving-based task. This again represents the observation of a form of strategy observed in our previous studies and discussed in 3.4.4.

Deferral of interruptions

One of the most frequent strategies or behaviours we encountered was the deferral of interruptions, which we observed across a total of 16 participants. This took the form of delaying attending to the arrival of a new set of values on the monitor screen, in order to proceed with a task already being undertaken. These deferrals varied considerably in length, ranging from little more than a couple of seconds in many cases, to approximately 18 seconds in one case (P6), and were observed across a variety of points of interruption, including when a participant was already engaged in operating a pump, when attending to the secondary task, and when moving between pumps. These deferrals helped our participants to complete subtasks or units of work, allowing for progress on a task to be suspended at a more 'meaningful' place (e.g. upon completing the process of entering a set of values, or having completed the transcription of a full row of values in the secondary task) which served to reduce working memory load (i.e. by reducing the need to preserve values for later recall upon task resumption).

Within the context of our 10-item scheme, these cases of deferral fall under the category of '*adjusting a procedure or behaviour*' (5.6) owing to their nature in terms of adjusting behaviour to modify task steps, to mitigate the anticipated vulnerability of a placekeeping error upon resumption.

Reordering sequence of secondary task

A single participant (P25) was observed to fundamentally adapt their process for completing the secondary task by changing the order of the sequence of their actions. The second task, as described previously in 8.4.3., required participants to scan through a list of values and record those containing a decimal point onto a second sheet. All participants prior to P25 had completed this 'sequentially' by searching through the list of values, and then upon identifying a value containing a decimal point, immediately moving to record the value. In this case, while the participant initially began by following this process, upon their first interruption, they subsequently divided the process into two distinct stages. This involved an initial stage of scanning through the list of values and using a highlighter pen to flag

and disambiguate the decimal point values, but not recording them. Upon highlighting all such values in this first step, the participant then recorded all the highlighted values as the second part of their own two-stage process for completing the task, striking through the (already highlighted) values as they recorded them.

Upon debriefing, the participant described finding the interruptions disruptive and thought moving to this adapted process would make the task easier. Indeed, the resulting procedure, while incorporating an extra step and requiring the process of 'scanning' through the values effectively twice, could be seen as more resilient to interruptions in some ways- during the initial stage of the process the point of resumption was 'fixed'. Rather than potentially resuming the secondary task and having to determine whether they were in the process of identifying a value or in the process of recording it, or what the last recorded value had been, the participant knew to simply proceed with the identification and highlighting process.

While we determined the primary 10-item scheme category represented here was in *adjusting a procedure or behaviour*, owing to the adaptation of the process, the strategy additionally incorporates elements of *separating task items* (splitting into two steps and the use of highlights to differentiate values) as well as *creating new cues* both in terms of the highlights as well as strikethroughs to track progress. We would thus very much consider this as representing a compound strategy.

80.5	60	45	90.5	600	200	480	930	30	10
360	50	55	10.5	90	250	750	10	80	65
240	940	750	1200	10.5	80	95	350	80.5	5
240.5	840	550	15	80	65.5	25	800	720	100
65	950	1000	35	85	90.5	20	400	25	60.5
45	300	605	300	95.5	10	850	340	345	20.5
85.5	30	75	100	900	75.5	80	25	200	10
90	80	60.5	200	120	430	20	305	90	200

Figure 31. Paper Materials Demonstrating a Reordered Sequence for Secondary Task

8.5.2.4 Adapting Physical Task Layout

We noted three implementations of strategies involving rearranging or adapting the physical task materials in order to optimise the layout of the task, mitigating a challenge we had intentionally designed into the paradigm whereby the two pumps were located on opposite sides of a desk and not viewable simultaneously. This included the moving of a pump, the moving of the materials used to complete the secondary task, and relocating to make use of a reflection in order to be able to concurrently monitor both pumps simultaneously.

Moving the pumps

In one case, we observed a participant (P1) physically moving a pump in order to reorient it so the contents of the screen on the pump would be easier to view, and viewable at the same time as the other pump (Figure 32). This served to facilitate monitoring, to help ensure the participant was aware when a pump had completed processing a set of values.

We determined that the strategy was primarily an example of *adjusting a procedure* or behaviour, however was also motivated by a desire to *manage* (informational) *resource availability* and thus comprised a compound strategy.

Figure 32. A Participant Repositioning a Pump

Moving the secondary task sheets

A total of 9 participants were observed to move the paper materials necessary for the completion of the secondary task, either to a vacant space on the desk between the two pumps (the optimal position for being able to monitor both pumps with minimal movement, and being able to move to each pump equally quickly; observed in 6 cases) or to carry the paper materials with them as they moved between pumps so they could work on the secondary task while attending to each pump (observed in 3 cases). In so doing, participants optimised the workflow of the task by reducing the time spent moving between pumps, and maximising productive time (i.e. time spend either interacting with either pump or completing the secondary task). We considered each of these strategies as representing examples of *adjusting a procedure or behaviour* owing to the modification of behaviour to optimise task steps, with no other items from our 10-item scheme being represented, and thus no instances constituting compound strategies.

Use of reflection for concurrently monitoring pumps

One participant (P7) made use of a vulnerability in the physical layout of the task paradigm in order to concurrently monitor both pumps using a reflection in the two-way mirror between the study room and the control room where the experimenter was situated. This reflection in the glass of the mirror had been noted by the experimenter prior to the conduct of the study however was unavoidable owing to practical constraints with the physical apparatus used. While it was difficult to directly observe and verify cases where participants might be utilising this reflection, as a means to recognise the impact of this variable, each participant was asked during debriefing whether they had noticed and used the reflection, with only P7 confirming that they had. The participant described how they had noted the opportunity when moving between pumps (as these reflections were only viewable from a specific location, owing to computer screens being used to effectively 'block' the reflection from the locations of both pumps) and had subsequently repositioned their chair and the secondary task in order to capitalise on this opportunity to monitor

both pumps simultaneously. We regarded this strategy as an example of *appropriating a resource* in the form of appropriating the two-way mirror as a means to perform this concurrent monitoring.

8.5.2.5 Checking

We observed a number of instances whereby participants incorporated checks to minimise the risk of making errors in the secondary task. This is an example of a resilient intervention on the part of our participants despite there being no request or requirement to conduct any such checking. We derived the theme of checking as a combination from two observed strategy groupings; conducting a post-hoc check of the secondary task, and redoing the task after a suspected error.

Post-hoc check of secondary task

A total of 10 participants were observed conducting a post-hoc check of the secondary task. This involved checking the list of decimal point values participants had composed against the values list from which they had performed the transcription task, in order to ensure they had captured all of the requested values containing decimal points. Towards the end of the paradigm, the majority of participants had completed the secondary task while they were still in the process of the primary task (entering values into the pumps) and so found themselves with idle time, perhaps explaining at least some of these post-hoc checking cases. Naturally, in cases where participants had been in more of a rush or were completing the secondary task up until their session finished, they had less available idle time and so were less likely to be able to undertake this checking, meaning that if the paradigm had been extended further and all participants experienced this same level of idle time, perhaps checking may have been more prevalent still.

All of these 10 cases were primarily considered as manifestations of our scheme item '*checking before or after an action'* as they represented checks to ensure the required actions had been completed (as described in our 10-item scheme)

however we noted that in 6 of these 10 cases, participants also utilised the *creation of cues* as a means to track progress through the process of checking, in terms of ticking or striking through values as they performed their checking, thus representing (albeit relatively simple) compound strategies.

Redoing task after suspected error

In a strategy that was identified during the debriefing discussion with one of our participants (P15), a variation of the practice of checking was noted whereby a participant believed they had erroneously omitted one or more of the values as the result of an interruption and attending to the primary task. The participant therefore opted to redo the secondary task as they felt this approach did not add significant complexity compared to individually checking each item they had recorded up to that point. In so doing, they therefore had two copies of the task which were available to cross-reference and check against each other to ensure accuracy.

We regarded this strategy as primarily an instance again of '*checking before or after an action'*, however we noted that in demonstrating awareness of a potential precompletion error and demonstrating a resilient response to mitigate this, the strategy also encompassed an element of '*precompletion awareness'*, and therefore represented a compound strategy.

8.5.2.6 Organising and Optimising Information

The final groupings of strategies we identified addressed the organisation and optimisation of information as a means to assist performance. This took the forms of composing additional and supplementary instructions or annotations for clarification, and actions to organise and structure the presentation of information used in the secondary task sheets.

Writing additional supplementary instructions

Two participants were observed to jot down additional notes or instructions to assist with comprehension or serve to assist memory in terms of instructions for completing the tasks.

One participant (P20) used the incorrect procedure when entering values into a pump, meaning they would be unable to complete the primary task and thus requiring the intervention of the experimenter to reminder the participant of the procedure and reset the interface (see left of Figure 33). Upon being provided again with operating instructions, the participant made brief notes to help ensure that they did not make the same error again (see top right of Figure 33).

Another participant (P22) made a very brief note on the paper materials used in the secondary task (see lower right of Figure 33) which served as a reminder of the values they were attempting to find and record. In this case, no error was made, nor experimenter intervention requested, however the note was pre-emptively made merely made to serve as a reminder to reinforce the task at hand.

Within the context of our 10-item scheme, we would consider both of these instances to represent the scheme item '*reinforcing an existing safety barrier'* owing to their quality of reinforcement of the existing instructions, which themselves represented a barrier to error. No additional scheme items were identified when considering both strategies, meaning that we would not conceptualise either to comprise any compound aspect.

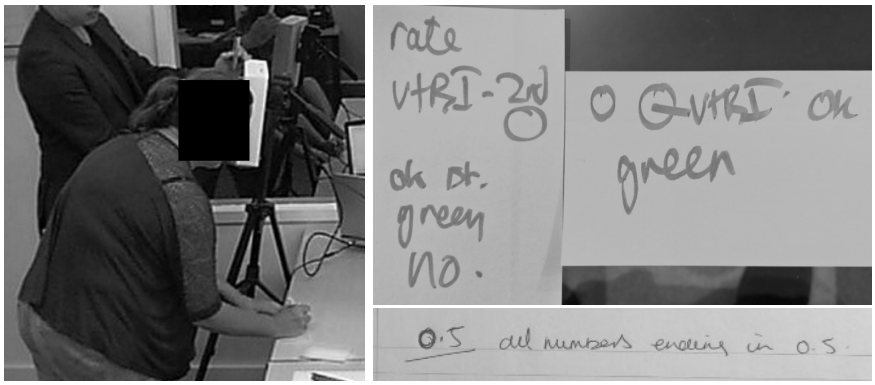


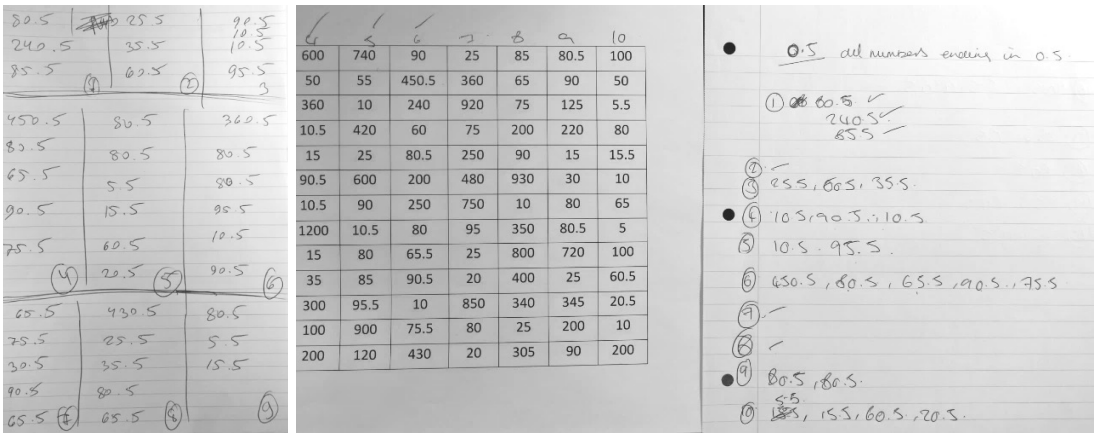
Figure 33. The Use of Participant-Generated Supplementary Instructions

Organisation or structuring of secondary task list

Observed across 5 participants, a final resilience strategy we noted was the organisation and structuring of the presentation of the list of values participants generated in the secondary task. This ad-hoc structuring of the list of transcribed values varied in exact form between participant, but as shown in Figure 34, took the form of grouping values based either by row (P19, left of figure), by column (P22, centre and right of figure) or by page (remaining 3 participants), as they appeared on the printed list of values. In some cases, labelling was added to the printed list to support this structuring, as shown in the centre of the figure.

Participants gave differing reasons for displaying this strategy, however as indicated by participants during the debriefing, the presentation of this information in an organised manner could facilitate both placekeeping upon resumption following an interruption during the conduct of the task, as well a post-hoc check for accuracy following the transcription of all of the values.

We regarded these strategies to be representations of our scheme item *Separating task items* as this describes the function these organisational and structuring schemes essentially served, by separating what would otherwise have been a long list of values into more meaningful and traceable groupings.



600	740	90	25	85	80.5	100
50	55	450.5	360	65	90	50
360	10	240	920	75	125	5.5
10.5	420	60	75	200	220	80
15	25	80.5	250	90	15	15.5
90.5	600	200	480	930	30	10
10.5	90	250	750	10	80	65
1200	10.5	80	95	350	80.5	5
15	80	65.5	25	800	720	100
35	85	90.5	20	400	25	60.5
300	95.5	10	850	340	345	20.5
100	900	75.5	80	25	200	10
200	120	430	20	305	90	200

Figure 34. Two Examples of Organising and Structuring the Secondary Task List

In the discussion following, we consider the implications of these findings in the context of our aims and objectives, and of the 10-item scheme for categorising resilience strategies. We moreover consider how our notion of compound strategies applies to this data, including by illustrating the application of our framework for the deconstruction of compound strategies onto some of the richer and interesting cases reported above to draw new insights into the nuances and details of these more complex cases.

8.6 Discussion

The current study aimed to investigate the variety of resilience strategies that could be observed within the confines of a controlled laboratory study paradigm, building upon our initial controlled study conducted at the outset of this work (reported in Chapter 4). Unlike the earlier study however, the current investigation assumed the approach of studying any and all strategies encountered, as opposed to focusing only on a specific subset or type of strategy. We therefore sought to expand the breadth of the initial controlled study in terms of strategies investigated, whilst also applying methodological lessons learned in the initial investigation (Chapter 4) to develop and demonstrate an improved and more robust methodological approach for conducting a controlled study of resilience strategies.

A key aim of this study was additionally to demonstrate and validate our theory-building work to date, in terms both of our 10-item scheme for describing and classifying strategies, as well as our framework for the more detailed analysis and deconstruction of compound cases of resilience strategy use. The study therefore was motivated by a desire to capture compound strategies with a degree of richness that would enable more fine-grained analysis of these complex cases, illustrating the utility of our framework and the opportunities that a structured, detailed analysis of resilience strategies may present moving forwards.

Finally, in a first-step towards establishing patterns between resilience strategy use and the types of threats they address, the data provided by this study

extended us an opportunity to consider the consistency of any threat-strategy associations identified from earlier work, and to see whether such patterns may be identified here. The identification of recurring apparent relationships across our previous studies between threats or disturbances and corresponding strategies would represent an observation that in itself serves to reinforce and further partially validate of the stability of our broad approach, illustrating an element of consistency and continuity across our findings.

The study elicited a relatively high frequency (n = 94) and broad variety (with some 17 strategy groupings, spanning 6 high-level themes) of cases, with resilience strategies being identified in some capacity across the entire sample. As had been previously observed, the extent to which participants utilised resilient strategies in their task performance varied considerably, as did the prevalence of different types of strategy across the sample. However, a notable finding remains (as was encountered in our opening study) that even within the fairly constrained conditions of a controlled paradigm, individuals are able to generate both a high frequency and rich variety of novel ad-hoc resilience strategies, serving again to demonstrate the ubiquity and prevalence of behavioural resilience. We situate these strategies within the context of our existing practical and theory-building work in the following discussion.

8.6.1 Application of Categorisation Scheme and Framework

In Chapters 5 and 7, we presented empirically derived theory-building work to facilitate the analysis of resilience strategies, in the form of a categorisation scheme to assist in articulating and classifying conceptually similar strategies, and a framework to support the deconstruction of compound cases where conceptual overlap is evident, reflecting multiple resilience qualities within a strategy. These theoretical contributions informed our analytical approach in the present study, a process which in turn helps to demonstrate the validity and efficacy of the theory driven analytical tools we have developed.

With regards to the function that our categorisation scheme served, upon gathering a variety of strategies from our controlled task, the 10-item scheme helped to provide an element of structure to support our analysis, articulating commonalities between strategy instances from which we were able to form our 17 strategy groupings as reported in Table 8 in our findings. The resilience concepts articulated across the 10 scheme items proved valuable in identifying conceptual similarities across instances, as well as establishing conceptual separation between groupings that informed the deriving of our 6 high-level themes. While we leveraged an established analytical approach in adapting thematic analysis as described by Braun and Clarke (2006), the initial grouping of related concepts to form codes is still a process that benefits from a foundation to aide in cursory analysis and sensemaking.

As had been the case when we came to analyse some of the strategies noted in the initial study, as well as the entries we gathered during our follow-up diary study, a number of cases were encountered which seemingly incorporated multiple simultaneous resilience qualities. These were identified during our application of the 10-item scheme, in cases where multiple scheme items appeared potentially appropriate, indicating the presence of multiple resilience goals or mechanisms at play. Prior to our identification of the notion of compound strategies, these cases would have represented outliers within the context of our scheme, requiring an exercise of determining and selecting a 'best fit' category. Stemming from the work outlined in the previous chapter however, we are now able to conceptualise these cases as compounds, reconciling them with the 10-item scheme by considering appropriate primary and secondary scheme items. Moreover, the framework we developed allows us to unpack and deconstruct these complex cases. For an example of this, we can consider some of the more complex implementations of using Post-it notes to record values as part of the primary task.

While variations existed in the exact manner in which different participants utilised these Post-it notes, one practice we observed was for participants to record incoming sets of values onto a single Post-it note, and then to either attach notes to their corresponding pumps, or separate the notes into piles on the desk in front of

them. Participants would then either strike-through or discard notes (by either scrunching them up, or placing them into a discarded pile), once the values they contained had been entered. Such a process represents a seemingly cohesive behavioural sequence and can therefore be conceptualised as a single strategy, despite the multiple activities being undertaken here, which present a complexity that is challenging to analyse if consulting only the 10-item scheme. However, such a strategy, we would now argue, comprises a compound strategy that incorporates multiple resilient mechanisms and motivations, and our framework can support the articulation of these and even support comparisons between these subtle variations or how such a strategy is implemented.

The primary motivation (MO1) for such a strategy is to reduce the risk of error, i.e. by ensuring that values are not forgotten prior to entry into the correct pump. A secondary motivation (MO2) in this case would be performance related, in terms of increasing the efficiency of task completion. The intentions in this example could be said to be threefold; (I1) making a record of each value (I2) ensuring the pump to which each value corresponds is discernible, and (I3) making it clear which values have yet to be entered, and which have been completed. We would posit that I1 and I2 correspond to MO1, while I3 relates both to MO1 and MO2. The actions comprise of (A1) recording values onto notes, (A2) strategically placing notes either on pumps or into separate piles, and (A3) discarding completed items upon entry. Here, A1 corresponds with I1, A2 corresponds with I2 but also I3, since the presence of a note visible on a pump can serve as a clear glanceable reminder that such a value has yet to be entered) and A3 relates to I3. These actions incorporate multiple resilience mechanisms: A1 describes the *Creation of artefacts* (ME1), A2 represents *Separating task items* (ME2) and when placed on pumps and used as a visual reminder, *Creation of cues* (ME3) and A3 describes the *Management of resources* (ME4).

The example above illustrates how the framework can serve both as a lens through which to examine and deconstruct compound strategies, but also additionally facilitate analysis regarding the effectiveness of different variations of

strategies. For example, as described some participants placed their 'Post-it notes' on the desk in front of them while completing the secondary task, as opposed to placing them on the pumps. This may initially appear a trivial distinction, however the presence of notes on or immediately besides the pumps (ME3) generated a salient and glanceable visual cue, while participants who kept their notes in one location removed from the pumps had less attentional support to assist them in completing their task. In other variations of the strategy, a small number of participants omitted I3 and A3, which subsequently increased the risk of errors of repetition whereby sets of values were added a second time erroneously.

In another case, we can use the framework to deconstruct instances whereby post-hoc checking was displayed in order to reduce the risk of error, by confirming the accuracy of the secondary task, a strategy that was utilised by 10 participants. In 4 cases, this was seen to represent a simple, i.e. non-compound strategy. Our framework can indeed still be applied to such cases, as follows: The motivation for this strategy (MO1) is to prevent errors. The intention (I1) is to confirm the accuracy of the values written down, which is realised by the action (A1) of proceeding through the participant-generated list of values and cross-referencing this with the printed task values list to check that all relevant records have been transferred or transcribed. Owing to the nature of this strategy representing a check that takes place after the primary conduct of this task, we identify the mechanism (ME1) in this case as being *Checking before or after an action*. In the other 6 cases that were identified as checking however, we noted an additional observable action (A2) in the form of marking values as they were being checked, which represents the additional mechanism of *cue creation* (ME2) in order to track progress during the course of the checking (I2).

This example perhaps illustrates two features of the application of our framework, the first being that it can be applied to non-compound cases, however in doing so arguably reveals limited insight in and of itself, but more usefully it also demonstrates how an additional 'strategy within a strategy' can be identified, articulated (in terms both of its observable action, and traced back to an additional

goal or intention) and reconciled with the 10-item scheme if conceptualised as a set of mechanisms (i.e. by identifying the additional cueing quality of the compound version of the scheme). While this level of detailed investigative scrutiny is not afforded by the mere 'best fit' application of the 10-item scheme as a categorisation exercise, indeed some of the tacit features of the strategy would be lost if merely labelling such cases as 'checking' only, the application of our framework serves to highlight these additional features of the strategy, informing a more in-depth analysis. This kind of exercise can help us to consider how one implementation of a strategy (i.e. the compound manifestations whereby additional markings are made) may be more robust or effective, particularly to interruption as indicated by I2, than another implementation of a very similar strategy (the non-compound version, in which we note progress isn't tracked).

A further example of the application of our framework to the strategies observed in the current study serves to again show how we can leverage a more fine-grained analytical approach to articulate multiple features or components, and how the identification of these can move us toward considering the conditions and context necessary for the implementation of strategies. In one case for example, a participant (P22) sought to reduce the risk of error (MO1) by ensuring they resumed the secondary task in the correct place upon interruption (I1). They did this by carrying the secondary task around with them (A1) and keeping their finger on the last value attended to (A2) which served as a visual *cue* (ME1). In a similar variation of this, another participant (P16) developed a strategy with the same motivation and intention, however instead used a different action whereby they left the pen on the desk pointing at the last attended value, so this became their only action (A1) but the strategy reflected two mechanisms, *cue creation* (ME1) and *appropriation* (ME2) by appropriating the pen to serve as the cue. This may again appear an unremarkable distinction, but by articulating the different actions and mechanisms at play, we can consider the implications of potential variations in the task paradigm. Both cases demonstrate dependencies: in the former, A1 is a pre-requisite for A2, while in the latter, the availability of the resource (ME2) is a necessity to enable the cueing

implementation utilised (ME1). Transferring these principles into a hypothetical real-world scenario where the paradigm may be liable to change, one can envision scenarios whereby variability or transience in either the physical conditions or availability of resources may not allow for either strategy to occur, hampering the potential for similar resilience strategies.

By applying the analytical apparatus (i.e. the categorisation scheme described in Chapter 5, and framework presented in Chapter 7) we developed in previous chapters, this work demonstrates how we can better study and understand strategies, both in terms of identifying broader groupings and themes by structuring the analysis of a variety of strategies, as well as how our framework can facilitate a more detailed consideration of richer and more complex cases, by disentangling multiple resilient components or features and helping to articulate additional functions and qualities. We consider how this exercise serves to validate these analytical apparatus' in the discussion continuing below.

8.6.2 Validation of Categorisation Scheme and Framework

In this discussion, we elaborate on how the data gathered during this study and the subsequent application of both our enhanced 10-item categorisation scheme as well as our framework for the deconstruction of resilience strategies has served as a means to partially validate our new analytical approach and apparatus.

Turning initially to the 10-item categorisation scheme we discussed in Chapter 5, we note that none of the items we gathered during the course of this study fell beyond the conceptual coverage of the 10 scheme items. This represents an important finding as it supports our assertion that the scheme is sufficiently robust to accommodate any and all observable resilience strategies, at least based on our combined experiences with the mixed and collaborative datasets used in initial validation (Chapter 5), supporting diary study data (Chapter 6) and now this additional and unrelated round of data from a controlled study (current chapter). We would concede that such a validation, in order to be considered fully exhaustive,

would benefit from additional studies and pools of new resilience strategies, however it is encouraging that among several hundred strategy instances gathered across a variety of methodological approaches, we are unable to broaden the coverage of the scheme further, suggesting at least a very strong degree of conceptual coverage.

With regards to the variety of different concepts described in the 10-item scheme, we note that of the 10 scheme items, 9 were represented to varying degrees across the data collected in the current study. The only exception to this was the item *Substituting a resource* which describes the substitution of a usually available resource with a spare or alternative. Given that for our participants, this was a previously unencountered task and thus no resources could be considered 'usually' available, this scheme item was not applicable within the paradigm we established here, hence not being represented. As labelled within Appendix F, we noted instances of *Managing resource availability* in moving pumps to maintain visibility of the secondary pump, *Appropriating a resource* in utilising the pen as a cue or one of the paper task sheets as a resource to occlude another, *Creating new cues* in the placement of Post-it notes and use of plastic tabs amongst other cues, *Creating new artefacts* in the composition of structured lists or semantically rich and organised Post-it notes, *Separating task items* in the structuring of the secondary task list or separating Post-it notes into piles, *Reinforcing an existing safety barrier* in the composition of supplementary instructions, *Adjusting a procedure or behaviour* in adapting the task layout and moving secondary task items, *Checking before or after an action* in the post-hoc checking of the secondary task, and *Pre-completion awareness* in recognising an error prior to task completion and redoing the secondary task accordingly.

The data collected during this study therefore demonstrated the utility of the categorisation scheme in shaping initial sorting and grouping, and understanding the breadth and variety of strategies gathered, as well as validating the 10 items we arrived at upon our development of the scheme. As noted previously however, cases persisted where multiple scheme items appeared appropriate for a given strategy, and in these cases we were able to demonstrate how our framework for the

deconstruction of resilience strategies can assist us in disentangling compound cases, and articulating multiple components and features of these more complex examples.

In the first example of the application of our framework described in 8.6.1, we show how the framework can help to 'unpack' episodes which incorporate multiple resilient intentions, actions and mechanisms. Over the course of this and the second example, we further show how this more fine-grained analysis, and the additional features and components articulated as part of it, can assist investigators in comparing and contrasting subtly different implementations of similar strategies. Finally in the third example, we again illustrate how the framework serves to articulate aspects of strategies at a level of detail that may be lost if merely classifying items as part of the categorisation scheme, and move on to consider how dependencies can be noted from the mechanisms and actions identified. Moreover, in the second example, we show how the framework can be used to deconstruct even non-compound, simple examples. As illustrated however, these more straightforward cases perhaps do not merit such a level of investigative scrutiny when compared to their more complex, compound counterparts.

8.6.3 Patterns Between Threats and Strategies

As discussed previously in 8.4.4., another aspect of this work we have taken first steps towards investigating is in establishing patterns between the types of threats, disturbances and challenges people may encounter, and the corresponding types of strategies or behaviours they may exhibit to mitigate and address them. While we do not possess a sufficiently rich understanding of any such relationships to enable formalised predictions and testing of threat-strategy associations, we have noted and identified first-pass preliminary patterns to this effect in a broad and relatively generic level of abstraction, which we described in 8.4.4. While these were only formed based on the conduct of our initial two studies, by conducting this third study we were presented with an opportunity to explore whether these broad patterns

were observable in this case, serving to demonstrate some early consistency in the forming of any such patterns.

While the phrasing and expression of our anticipated resilience responses varies between that presented in Table 7 (summarised from the anticipated patterns noted prior to the study and described in 8.4.4) and how we present our findings in Table 8 (derived directly from our observations post-study), we note that the broad level strategies and behaviours we predicted all materialised within the study. Moreover, in many cases, the strategies we anticipated observing were some of the more prevalent observed. This includes the creation of artefacts to support working memory, supplemental cues and annotation to assist progress-tracking, momentary deferral to manage interruptions, and reoganisation of the physical layout of the task to improve efficiency and optimise workflow.

It is worth noting at the same time that while our anticipated patterns were deliberately generic and high-level in nature, as described in 8.4.4 we anticipated the reorganisation of layout may involve reposition or reorienting the pumps, which was only observed in one instance, suggesting that the specification of precise strategy implementations may be premature at this stage. Similarly, one of the most prevalent observed strategies, that of performing checking, was overseen when we composed our list of anticipated strategies and behaviours.

As discussed previously in 8.4.4, we consider that we are still in the process of establishing a suitably robust foundation upon which to base formalised, specific predictions concerning how individuals will respond to a given threat. However, while the work described here does not establish a formal mapping of any such threat-strategy associations, in identifying potential broad patterns and demonstrating their prevalence across multiple studies, this work could be seen as a first venture into such territory. Considered as a proof-of-concept, with anticipated resilience responses being based upon only two prior first-hand studies, we would suggest that this component of the study was largely successful in indicating a potential future avenue which, we believe, would represent a useful approach for future work into resilience strategies. As discussed previously, we would argue that the establishment

of a set of reliable, specific mappings between threats and strategies could make these concepts more tangible, and ultimately move us towards applying this knowledge within the context of future design work. This is a notion that we revisit and discuss further in 8.6.4 and 9.4.3.

8.6.4 Evaluation and Implications

While the current investigation achieved its immediate objectives in terms of developing an improved methodological approach for the collection of resilience strategies in a controlled setting, collecting a variety of strategies that are suited to fine-grain investigative analysis, using these to apply and validate our 10-item scheme and framework for deconstructing compound strategies, and taking first-steps toward considering patterns between challenges and resilient responses, we also consider some of the limitations of this work here, and discuss implications for future work in the area.

One such limitation is that in examining strategies within the confines of a relatively tightly-controlled paradigm, one inevitably reduces the breadth of possible resilience strategies that may be encountered. In particular, presenting participants with a reduced number of predefined challenges and threats to performance, we see only a limited return in terms of *variety* of compound strategies. This is reflected by the fact that while 9 out of our 10 scheme categories were represented, there was by no means an even distribution of strategies across categories. Certain types of resilience strategy (e.g. those involving the creation of cues and artefacts, or the adjustment of behaviour or procedure) were far more prevalent, while others (e.g. managing resource availability or pre-completion awareness) were represented in only one or two cases. This is, however, a somewhat inevitable trade-off; by establishing a controlled paradigm with a specific task that affords us the ability to scrutinise strategies in-minutiae, one necessarily constrains the space of possible observable strategies. Moving forwards, this is a consideration that could be mitigated by conducting multiple similarly scoped studies using a variety of

conceptually different tasks, or, as we have, by combining the controlled study approach with other, broader approaches targeting the collection of resilience strategies across a wider range of contexts, tasks and settings (as demonstrated by our use of diary studies described in Chapter 6, and the incorporation of data from colleagues' further studies and approaches, as discussed in Chapter 5).

A further evaluative consideration, perhaps more specific to the implementation of the current controlled study, is in the instruction provided to participants and the challenge of extending participants the scope to develop and utilise strategies while limiting the propensity for participants to be 'nudged' into displaying strategies. When attempting to study participants' use of resilience strategies, there is a form of balancing act in terms of instructing participants that they 'can' or 'are able' to take certain actions, while not actively encouraging them to do so. We attempted to adopt a somewhat conservative approach here by, for example, informing participants that they were able to write on any of the materials in front of them, however not stipulating this as an expectation or requirement. Indeed some participants even missed this instruction and later informed the experimenter that they did not realise they could write on the printed sheets provided (although this actually resulted in the benefit of additional strategies to compensate for this, such as using the placement of a pen as a cue rather than using it to write and generate a cue).

This is a consideration that was reinforced in post-task discussions with some participants who described how they would have, for example, moved the pumps had they known they were able to do so. We can therefore speculate that we could have observed even more strategies, or more instances of some of our less prevalent strategies, had we instructed participants they were able to take such an action. It is worth considering however that to do so could at the same time have encouraged or nudged participants towards taking such an action on account of perceived demand characteristics. While the prevalence of one type of strategy over another was not a primary target of this investigation, we recognise that this aspect of instructing versus nudging is at least an evaluative consideration. Ultimately, we have not, nor

can we, establish an absolutely 'correct' level of instruction to provide to participants, however we would naturally encourage any researchers conducting similar investigations in future to reflect carefully on this consideration.

A further and more broad limitation of this current investigation is that some questions pertinent to the work remain largely unresolved. There are still some ambiguities that exist in terms of how one defines and scopes resilience strategies, a recurring theme throughout this thesis. One such aspect of resilience that remains open to interpretation is the notion of intentionality, or the extent to which one consciously and deliberately deploys a resilience strategy or alternatively enacts a strategy that appears resilient to a third-party observer, albeit subconsciously or unintentionally. Our observation of subjects verbally rehearsing or uttering values to assist working memory represents an example of this, with some participants mindful that they were doing so and able to describe their behaviour and its purpose, while others are seemingly unaware they have displayed this behaviour. As we have done in the past, we can see a logical argument for drawing a potential differentiation here between *resilience strategies* (intentional, conscious) and *resilience behaviours* (subconscious, not deliberate), and this is a distinction we recognise previously (3.5). As also described previously however, we adopt the position that the merit in considering one while excluding the other does not seem immediately apparent in the context of our work into individual resilience.

A final consideration (orthogonal to the scope of the current investigation) is in establishing any possible relationship between resilience (or specifically, types of strategy) and any potential performance effects. While we did analyse performance data during the current investigation, anecdotally we note that the participant who used fewest resilience strategies seemingly displayed one of the highest rates of error, while the participants utilising the greatest number of strategies did not tend to make so many errors. Ultimately we did not employ a sufficient sample size or data gathering approach to afford us the possibility to fully explore the possibility of whether increased strategy use (and in particular, use of specific types of strategy)

may directly lead to increased performance, however we note this could be a potential direction for future investigations into resilience strategies.

Considering some of the strengths of the current investigation however, the new format undertaken here represents a notable development in terms of our methodological approach when compared with the initial study, and illustrates how controlled studies can be used to bring insights into the use of resilience strategies. Moreover, this work provisionally indicates that patterns may be noted as to the types of strategies than can serve to mitigate different types of challenges and threats that users may encounter. The implications of this potentially could be harnessed to inform the design of technical and sociotechnical systems in future. For example, if we consider that progress-tracking strategies such as the discarding or occluding of enacted or no-longer-relevant information can support recovery from interruptions, designers may consider providing interface support to accommodate this functionality for users. Similarly, where information is transient and only available for a limited amount of time, support could be provided to enable users to effortlessly capture such information, reducing the burden on working memory.

If we can reinforce or articulate new relationships between threats and resilient responses, designers may also be able to utilise this information by 'working backward'; if user testing or real-world feedback indicates a persistent threat or challenge that is difficult to overcome in an automated fashion, support could at least perhaps be afforded for users to maintain their resilience, by better supporting the types of resilience strategy that are identified as being effective to counteract such threats or challenges. We would at this point acknowledge that the work described here represents only a first-step towards forming such knowledge at a level which could be applied as described above however, and that future work into reinforcing or articulating such relationships is required to provide this level of operationalisation and utility for designers. The current study does however present a potential template as to how this goal may ultimately be realised.

8.7 Summary and Contributions

The work described in this chapter represents empirical targeted investigation into different types of resilience strategy in a controlled setting. By developing and reimagining the controlled laboratory study approach initially utilised in our opening study, we demonstrate development in terms of methodological approach for the investigation of resilience strategies in a controlled study format. Referring back to our contributions and research questions as described in 1.2, we therefore demonstrate progression primarily towards RQ3 in partially addressing C4.

Utilising a newly designed task paradigm, the study revealed a variety of different types of strategy, recorded in sufficient detail so as to enable close examination, moving us again partially towards both RQ1 and RQ2. The data collected as part of this investigation moreover offered us the opportunity to apply the analytical apparatus we have refined and developed throughout the course of this thesis, in order to better understand and articulate the strategies observed, and served to support and validate the use of both our 10-item categorisation scheme and framework for the deconstruction of compound strategies, thus helping to form partially our remaining C1-3 contributions.

Chapter 9: Evaluation and Conclusions

9.1. Chapter Introduction

In this closing chapter, we begin by presenting a summarised chapter-by-chapter overview of the work that that has been undertaken during the course of this project. We then revisit the research questions described during the outset of this work, and provide a concise discussion of how the work in this thesis serves to address each. We also revisit the contributions that this work has provided, both in terms of our practical and theoretical contributions to knowledge surrounding the resilience of individuals, as well as our methodological contributions, and discuss why and how each contribution has been realised, and their potential implications in terms of informing the future investigation of resilience strategies.

Following this, we present an evaluative discussion which reflects upon the approach we undertook and some of the limitations encountered and lessons learned during the course of this work. We then more to consider how future work may serve to build upon the contents of the thesis in an investigative or research-oriented manner, before also considering how some of the key insights gained here could serve to inform the targeted evaluation of existing practice, as well as the design of future technical and sociotechnical systems.

The chapter closes with a concise personal reflection upon the notion of resilience strategies and the opportunities which may be afforded by its continued investigation.

9.2 Summary of Work Conducted

This thesis outlined multiple strands of work, encompassing both practical investigative and theory-building conceptual work. Following our introductory Chapter, the thesis opened with a broad literature review, targeting a number of established domains and fields in an attempt to provide a wide-ranging account on the central topic of how individuals develop and deploy resilience strategies to maintain or enhance performance. This literature review is presented both in Chapters 2 and 3, and is divided into two chapters covering different bodies of literature. Chapter 2 situated the topic by presenting the literature explicitly addressing Resilience Engineering or Cognitive Resilience by name, while Chapter 3 synthesised work from a variety of different disciplines that we consider pertinent to resilience while not making direct reference to it, with concepts that we identified and discussed which could both inform and be informed by the individual resilience perspective.

Chapter 4 introduced the first unit of practical work conducted to investigate resilience; a controlled study which sought to better understand how users implement one of the most prolific forms of resilience strategy, that of forming cues. More specifically, the study built upon existing work into how cues can enhance performance when interactions are disrupted by interruptions, by focusing on how users themselves may engage in the process of actively configuring cues. We reflected on some unanticipated observations and lessons from this work, both in terms of the phenomena observed, and also in terms of methodological considerations in investigating what emerged to be a challenging topic of study.

Chapter 5 described our initial unit of conceptual investigation, which served to address perceived gaps in the field that were identified following analysis of the study conducted in the previous chapter. While early work had been conducted by others into the area of identifying and articulating common strategy prototypes, in this chapter we presented a discussion of how developments were made to collaboratively expand and refine a categorisation scheme for classifying strategies,

with the scheme's original authors. This process, informed and supported by practical work presented both in Chapters 4 and 6, served to further develop a categorisation scheme for the classification of strategies and a common vocabulary with which to discuss and analyse what would otherwise remain largely anecdotal and informal accounts of real-world resilience strategy use.

Chapter 6 described our second unit of practical work, which took the form of capturing resilience strategies through self-report diary studies. The introduction of this novel and complementary approach (when contrasted with the controlled study presented in Chapter 4) allowed for us to better test the 'boundaries' between different types of strategy (explored in Chapter 5) by facilitating the collection of a much broader range of strategy accounts, spanning a wide variety of tasks and settings. In so doing, this approach augmented our previous controlled study by providing supplementary data of a different nature, leading to expanded conceptual coverage and facilitating new insights.

Analyses conducted upon the data gathered during the work described in Chapter 6 led us to undertake a second unit of theory-building work, which was presented in Chapter 7. This chapter described how, informed by our first-hand observations and analyses, we reconceptualised the nature of resilience strategies, introducing the notion of *Compound Strategies*. In this chapter, we discussed the implications of this new perspective, and introduced a conceptual framework to assist in the analysis and deconstruction specifically of complex cases of resilience strategy usage at, to our knowledge, a previously unprecedented level of granularity.

In Chapter 8, we described a final practical investigation in which we returned to the format of conducting a controlled laboratory study. This study, informed by our insights from the initial controlled study covered in Chapter 4, served three broad purposes: (i) it demonstrated development in a methodological sense by establishing an improved study format suitable for eliciting detailed reports of a variety of resilience strategies and demonstrated the potential usefulness of this approach, (ii) it served to validate and support our conceptual work in the form of the categorisation scheme and conceptual framework for the deconstruction of

compound strategies, and (iii) it represented a first step towards exploring the possible notion of common patterns between types of resilience strategy, and the types of threats or disturbances they address.

In the discussion that follows, we return to the research questions presented at the outset of the thesis, extract contributions and advances in knowledge obtained throughout the course of the thesis, and present an evaluative discussion of our work and drawing overall conclusions as to what we have learned during this undertaking.

9.3 Revisiting Our Research Questions

As described in Chapter 1.2.1, we approached this work with three broad research questions, which shaped our subsequent contributions (described in 1.2.2). Here, we discuss how the work presented throughout the thesis and summarised in 9.2 above serve to address each of these research questions, and where the insights gained throughout the course of this work form our four key contributions.

As outlined in 1.2.1, our first research question was as follows:

RQ1: What constitutes a Resilience Strategy, and what different types of strategy exist?

Given the limited pre-existing work directly investigating the topic of resilience strategies, a core objective of this work throughout has been to better understand what resilience strategies fundamentally are, and what types of strategies exist. As informed by our literature review, the original working definition we established was that resilience strategies can be conceptualised as:

Observable behavioural interventions that individuals utilise to pre-empt, adapt to or recover from threats or disturbances, in order to maintain or enhance performance and minimise error or risk.

This definition has remained stable throughout the course of our work, however as informed by our three practical studies and two units of conceptual theory-building work, we would further supplement this definition by articulating two additional concepts that fall under the 'umbrella' term of Resilience Strategies; *Resilience Behaviours* and *Compound Strategies.*

Resilience Behaviours: This describes observable actions that are more generally tacit in nature and do not appear overtly 'strategic' or deliberate on the part of those using them, for example the practices of verbally rehearsing information to retain it in working memory, or the dynamic adjustment of workload or task structure. While others may exclude such behaviours on the grounds of them seeming less intentional or more difficult for users to articulate (as discussed previously in 3.5), we have opted to consider such phenomena within scope of the current thesis as both the 'means' (observable behavioural adaptations) and 'ends' (management of threats/disturbances and enhanced performance) are effectively the same as more overt and strategic cases. This inclusion is motivated by our wanting to approach the topic in a comprehensive manner, in order to potentially *broaden* investigations of the topic. While these represent what could be considered as a branch under our broader conceptualisation of 'resilience strategies', and we have accordingly grouped strategies and behaviours for the purposes of this thesis, we articulate the concept of 'resilience behaviours' here in recognition of the fact that not all investigators may share our adopted position.

Compound Strategies: This describes resilience strategies that simultaneously combine multiple *motivations, intentions, actions* and/or *mechanisms* (as articulated in 7.4). Such cases were identified from our work to categorise instances of strategy use when it became apparent that some cases incorporate additional complexity and combine multiple aspects as articulated in our categorisation scheme. In order to investigate how these cases work, it can be beneficial to deconstruct them into more fine-grained and approachable units of analysis, an approach that is supported by our

Framework for the Deconstruction of Compound Strategies (7.4). The articulation of these compounds helps us to investigate strategies in greater *depth*, facilitating a more detailed understanding of the topic.

These broad concepts could be said to describe two over-arching 'types' of strategy, however we have also developed an account of the different types of resilience strategy that exist in a more specific sense. In Chapter 5, we presented work that collaboratively developed, expanded and refined a categorisation scheme which articulates 10 different types of resilience strategy, describing a range of concepts including the creation of cues, the appropriation of resources and the generation of artefacts (with the full scheme being available in 5.6). Our improvements to the scheme resulted in expanded conceptual coverage, as well as enhancements in the language used to express and describe scheme items as well as the boundaries between different types of strategy. We discuss this in more detail when we present our corresponding contribution, *C2*, in the section following.

In summary, the newly articulated concepts and revised and expanded iteration of our scheme to describe the different types of strategies that exist serve to illustrate how the work contained in this thesis has enhanced understanding on what constitutes a resilience strategy and what types of strategy exist, thus addressing our first research question.

RQ2: How do different types of strategy 'work':- What are the underlying components that contribute to the make-up and effectiveness of a strategy?

Our second research question sought to enhance understanding in terms of why and how resilience strategies work, and what are the functional components that contribute to this.

At a broad level, our aforementioned 10-item categorisation scheme helps to disambiguate different types of strategy, and as discussed in Chapter 5, illustrates how they work at high level of abstraction. Each item is presented with a descriptor and examples which convey the function behind each category, for example

generating cues and artefacts to mitigate lapses in memory, or different manifestations of the management of resources (in terms of maintaining availability, substitution and appropriation).

It was not however until we reached the work described in Chapter 7 that we developed a more in-depth appreciation of the 'mechanics' of strategies by deconstructing them and considering the components from which they arise. By adopting this new position and more fine-grained level of analysis, we presented a framework that supports the articulation of low-level actions and how these correspond to high-level motivations and intermediary intentions or goals that are formed when implementing a strategy. By providing structure to extract these details, it becomes possible to trace corresponding mechanisms (i.e. the concepts contained in our categorisation scheme) back to the observable actions a user takes, even in complex and entangled 'compound' cases of resilience strategy use. As demonstrated in our analysis described in Chapter 8, we can furthermore use this enhanced detail to compare and reason about the effectiveness of different strategy implementations.

We therefore now possess an enhanced understanding of how different types of strategy work at a transferable, high level of abstraction, as well as a framework to facilitate more detailed analysis of specific real-world cases, providing increased insight into how and why different resilience strategies work.

We consider the implications of this in our discussion of *C3*, our third contribution, in the section following.

RQ3: How can we identify and develop appropriate practical approaches for investigating Resilience Strategies?

Our investigations into resilience strategies have necessitated the creation of novel approaches to enable their investigation, again resulting from a lack of established work specifically addressing the topic. By harnessing investigative paradigms from the field of HCI, we have developed approaches for the targeted

investigation of resilience strategies through the use of both laboratory-style controlled studies, and self-report format diary studies.

Through the lessons learned and described during the course of this work, we have established a robust controlled approach for eliciting and capturing a variety of resilience strategies at a sufficient level of detail to support in-depth analysis (Chapter 8, building on the earlier work described in Chapter 4), as well a diary study approach that has given rise to a large pool of useful, varied and rich data (as detailed in Chapter 6). These both represent tailored approaches for the collection of data that support the investigation of resilience strategies which did not, in the forms described here, exist in the work prior to this thesis. These approaches can be adopted and adapted by others to help inform future investigations.

In addition to this, the work described in Chapter 5 demonstrated how we were able to collate and consolidate a number of further strategy accounts from a variety of other existing external studies which adopted a variety of further approaches (such as survey and situated observation data), which served to supplement the approaches developed first-hand here. Existing studies (including those not directly addressing resilience) can additionally be used to inspire and inform the establishment of controlled studies into resilience, in a similar manner to how, as described in 4.4.3, we took inspiration from the work of Li, Blandford, Cairns, & Young (2005) in developing our own controlled paradigm.

We further describe the implications of our corresponding contribution, C4, in the discussion that follows.

9.4 Revisiting Our Contributions

In realising the above research questions, we present and discuss four key contributions made during the work presented here. The first of these is as follows:

C1. A broad set of real-world strategies, collected from a variety of complementary empirical approaches, expanding the existing limited pool of strategies, to provide material for analysis

In order to investigate resilience strategies, it is necessary to possess a corpus of real-world strategy cases that form the 'raw data' to enable analysis. Prior to the work contained in this thesis, researchers looking to specifically investigate real-world cases of resilience strategy use could draw upon only a limited existing pool of data. While early efforts had been made by others to collate a set of appropriate cases (e.g. Furniss, Back and Blandford, 2014), this existing collection of strategy accounts was limited in terms of breadth (with a limited number of cases, many having been reported by only a handful of researchers) and depth (due to the brevity of strategy reports, a consequence of the method used to collect them). Where other cases were identifiable in the literature, these were often presented anecdotally and as tangential accounts of user performance in work targeting other aspects of HCI or human factors (for example Back, Brumby & Cox, 2010; Randel & Johnson, 2002).

We have established a substantially expanded pool of strategy accounts, utilising multiple data gathering approaches. The two primary approaches we adopted first-hand in order to achieve this consist of our diary study, described in Chapter 6, which develops on the aforementioned Furniss et al. approach, and through the collection of strategies within our controlled laboratory studies as described in Chapters 4 and 8. We additionally collated a number of further strategy accounts from colleagues who utilised a greater variety of approaches, including situated observations and survey data, as part of the work presented in Chapter 5.3.

By combining these complimentary approaches, we have been able gather data of increased breath (owing to larger and more varied samples of respondents across our studies, and a higher frequency of collected accounts, compared to the previous work in this area by Furniss et al.) as well as increased richness and depth (both by using probes in the diary study to elicit further detail, and by understanding and actively shaping the contexts in which strategies were observed in our controlled studies).

While this undertaking has served to build a robust foundation to inform our own investigations, informing the development and validation of the analytical apparatus described in Chapters 5 and 7, the corpus of strategy accounts gathered

throughout the course of this work may also be leveraged by future researchers looking to better understand resilience strategies, therefore comprising a contribution to the broader field of work into resilience. While we have included numerous examples throughout the course of this work (and an additional number of cases are presented in the attached appendices), we are in the process of preparing a further subset of anonymised and varied strategy accounts that will be available to inform future investigations and assist other researchers looking to better understand resilience strategies. For further details regarding the availability of this data, please contact the thesis author.

C2. An expanded and refined categorisation scheme for classifying different types of strategy, that enriches the theory base to help us understand, reason about and communicate instances of resilience

As discussed in our literature review (Chapter 3) and the work presented in Chapter 5, Furniss, Back and Blandford (2014) established an early categorisation scheme to articulate different types of resilience strategy. The original authors demonstrate the merit of adopting such an approach in terms of identifying and disambiguating distinct resilience concepts, and providing structure to support targeted analysis. This initial iteration of the scheme required further refinement however, as acknowledged by the original authors in the text, and as evidenced by ambiguities and gaps in coverage we identified from our initial study described in Chapter 4.

Our work, described in Chapter 5 and informed by data gathered during Chapters 4 and 6, served to gather and leverage an expanded pool of real world strategy cases in order to collaboratively develop and improve this scheme. Key developments included an expansion of conceptual coverage resulting in a scheme that accounts for a broader variety of strategies (including those not accommodated by the original iteration), as well as improvements in the conceptualisation of

individual scheme items, resulting in a richer scheme with enhanced terminology, supplemented with representative examples to improve clarity and applicability. We then describe how we validated these improvements through an iterative combination of workshop and collaborative discussion activities and inter-rater assessments.

This work has not only served a useful function throughout this PhD in the concepts we identified, but can be leveraged by future researchers and practitioners working to better understand behavioural manifestations of resilience, by providing a vocabulary to consider and discuss strategies and a set of empirically derived categories to structure and inform analyses. By helping to identify and make sense of different types of strategy, our improved scheme can help to provide an overview of the variation across strategies, and moves us towards the possibility of applying insights from investigations into resilience in a more concrete design sense. As we consider in Chapter 8, by possessing an understanding of different types of strategy, moving forwards we foresee scenarios where patterns can be articulated between the types of threats and disturbances users face and the corresponding resilience strategies that can be used to mitigate them, knowledge which could be harnessed by designers looking to enhance and accommodate for users' resilience. The establishment of a robust and validated scheme for articulating different types of strategy thus lays the groundwork for future investigators and practitioners to better understand strategies, and makes the topic of resilience strategies more tangible, useful and ultimately applicable.

C3. A conceptual framework that helps researchers articulate and reason about the properties of complex examples of resilience strategies, identifying underlying components and how they relate

While prior work had been undertaken to analyse resilience strategies in terms of breadth and variety (i.e. Furniss et al.'s (2012) categorisation scheme), we noted during the course of investigations that some resilience strategies encompassed

a level of increased complexity in how and why they were realised. Our attempts to analyse these cases highlighted a lack of any established foundation of work in the area of resilience strategies to facilitate more low-level, detailed examination of the intricacies of individual strategy manifestations.

In Chapter 7, we moved towards investigating resilience strategies to a greater degree of depth in order to account for this richness and complexity, by building a picture of underpinning motivations and functional mechanisms. This represents an undertaking that, to our knowledge, had not been conducted specifically in the area of resilience strategies in the limited existing work on the topic. In so doing, we identified the notion of *compound strategies*; more complex and often entangled cases that combine multiple elements or resilience components, and warrant a more fine-grained level of analysis. The framework we consequently built provides support for deconstructing these cases into their constituent motivations, intentions, actions and mechanisms, facilitating a closer level of investigative scrutiny and identifying new insights in terms of how strategies work and how different implementations of a strategy can be compared and contrasted (as described in Chapters 7 and 8).

The framework we present in Chapter 7 can help future researchers and practitioners to better understand the complexity of resilience strategies, drilling down to their constituent components in more detail. This can further be used in combination with the aforementioned categorisation scheme to build a rich picture of how and why individuals display strategies, and how these different strategy implementations work.

By harnessing the structured approach for decomposing compound cases as afforded by our framework, future investigators have a foundation to consider the functional intricacies of strategies in a manner which again makes previously tacit knowledge more tangible. This richer picture also has potential implications that could inform design in terms of assessing and better understanding users' resilient responses in a given interaction, and considering how features or design

interventions may impact or accommodate the propensity for compound resilience strategies in future systems.

C4. Demonstrating the potential value of different approaches for eliciting, recording and analysing instances of resilience

In order to build an enhanced understanding of resilience strategies, we require robust and reliable approaches for their targeted investigation, including practical means to gather and collate strategies in a manner which allows for their detailed analysis. Given the limited existing work directly addressing the topic of resilience strategies, one further contribution of this work was in establishing appropriate approaches to gather the necessary data to enable learning about resilience. In Chapters 4, 6 and 8 we present thee studies, each of which demonstrates advancements that help to furnish this broader methodological contribution.

In Chapter 4, we present an initial investigation that deployed the novel approach of developing an artificial task paradigm generated specifically for the purpose of eliciting resilience strategies in a controlled setting. Our practical choices in terms of implementing the paradigm, as discussed in Chapter 4, yielded some unanticipated challenges and results, however proved ultimately highly insightful. These insights not only took the form of our findings into resilience, shaping the subsequent direction of this work, but also in terms of providing methodological lessons on the conduct of investigations to capture resilience; lessons (outlined in 4.7) which could potentially serve to benefit future researchers as they have supported the work later presented in this thesis.

The work presented in Chapter 6 covers our use of a paper-based diary study, which while taking inspiration from Furniss, Back and Blandford's (2012) '*twitter* diary' approach, also demonstrates methodological advancements. Our work here served to demonstrate the feasibility of leveraging a more conventional and established paper-based diary approach to deliver self-reported resilience strategies,

and in greater volume and detail than comparable accounts captured via *twitter*. Lessons for future researchers can be extracted in terms of the (now demonstrated) potentially utility of the approach, the practical arrangements of our study (including the physical diaries used and prompts generated to probe respondents for enriched contextual information, and use of post-hoc questioning to clarify entries where required), and the finding that full saturation was still not observed after a duration of two weeks.

Chapter 8 revisited the approach of investigating resilience strategies in a controlled laboratory-type study, and demonstrated both practical advancements in the implementation of our paradigm (for example, in terms of task design and the capturing of richer and more useful data) and data analysis approach (informed by both the theory building work undertaken during this thesis and the off-the-shelf, established approach of thematic analysis). Through revising our task setup in particular, and building upon insights yielded throughout the course of our work, the study also illustrates how future investigators could move towards establishing preliminary predictive power in terms of mapping out potential associations between strategy use and the nature of threats or challenges presented. By leveraging and developing our approach as a template, we believe further insights to this end could be obtained.

Considering our studies in combination, the work described here also provides a further finding that could be leveraged by future researchers looking to investigate resilience strategies, in terms of demonstrating the value of combining a mixed-methods approach to collect strategy accounts. We note that the prevalence of reports of different types of strategy may vary with the approach used to collect data. For example, future researchers looking to focus more on behavioural rather than strategic resilience manifestations would be advised not to limit their strategy collection approaches to those requiring self-report, owing to a tendency for behaviours such as verbal rehearsal or task restructuring to be more difficult for users to themselves identify and articulate

Our work to demonstrate the potential value of different approaches for investigation resilience strategies therefore contributes useful knowledge for future researchers, providing a starting point and a number of practical lessons to support the collection and analysis of resilience strategies, particularly with reference to harnessing controlled and self-report diary studies.

9.5 Revisiting our Preface Example

At the outset of the thesis, we opened with a preface giving a fictional but arguably realistic account of a few potential everyday resilience strategies one might observe in the case of a hospital nurse tending to a patient. The account was as follows:

> *Jane's time is precious. She works in a busy hospital ward, and often has to juggle multiple tasks, in a stressful and unpredictable environment. This is why it is all the more frustrating when, after taking several minutes to compose an entry into the system, she clicks 'submit' and is greeted only by an error screen telling her the connection has been lost. Her Ethernet cable is loose, and this has caught her out before.*
>
> *Fortunately, before clicking 'submit', Jane intentionally highlighted the text in the field and copied it onto the clipboard, so at least she won't have to type it all again.*
>
> *She locates and reinserts the cable, however this time, she borrows an elastic band and uses it to hold the cable in place, better securing it, albeit temporarily.*
>
> *Right at that moment, her watch begins to beep. This is the timer she set up earlier, telling her Mr Jenkins' infusion pump will shortly reach the end of its infusion.*
>
> *She quickly opens up a window on the machine to compose a new email, and types 'tech support' into the subject heading, pasting the text she*

nearly lost in the body of the message. Also before leaving, Jane grabs a post-it note and scribbles 'Jane logged in, back in 5 minutes', before sticking this note onto the centre of the screen.

Jane attends to Mr Jenkins, pre-emptively silencing the pump alarm, since his dementia causes him concern and agitation when these alarms sound.

After attending to him, she returns to her desk where the 'email' prompts her to paste the recovered text back into the system, and report the cable issue to tech support. She writes another note, to advise colleagues of the issue, and that it has been reported.

This fictional anecdote illustrated how seemingly insignificant behavioural interventions in the form of resilience strategies can be used to enhance performance and minimise error. At the same time, such episodes rarely go investigated or reported, meaning that the positive contribution such resilience strategies make to the safety and functioning of such a scenario are often overlooked and usually, never fully capitalised upon.

At a broad level, the perspective taken during this work serves to demonstrate the potential value in adopting a resilience perspective to the everyday interventions of frontline operators, opening up a previously largely unexploited space of behavioural accounts that can help designers better understand 'work as conducted', and help to identify frailties and opportunities within interactions with technology and wider operations.

Further to this, until recently only a very limited amount of work had been conducted into establishing a vocabulary with which to specifically articulate these resilience concepts at a behavioural-strategy level of granularity. The work conducted as part of this thesis has helped develop this vocabulary, meaning we can now recognise distinct strategies as units of analysis, including the recognition and analysis of a number of different types of strategy. Taking our preface example, we can talk about the creation of a cue in the watch alarm, the creation of artefacts with the onscreen email and post-it notes, appropriation in the case of the elastic band and

email program, and the adjustment of a procedure to reinforce a safety barrier in the copying of the text. By better articulating these concepts, we make them more tangible, supporting analysis and assisting with transfer of subsequent insights across settings and contexts.

Our framework for the deconstruction of compound strategies can also support a deeper analysis of cases where complex strategies are noted, by breaking down these accounts to consider the previously entangled multiple resilience strategy elements at play. In our example, by copying the text into an empty email, Jane is motivated both by a desire to preserve the text, but also to remind herself to action it and report the problem. By appropriating an empty email, she is able to create an artefact preserving this text, which also performs a cueing function upon task resumption.

In order to develop ways to leverage resilience strategies, it is necessary to have a working understanding of them; the variety that exist, and how and why they function. We would argue that the knowledge developed during this thesis helps further understanding in both cases.

9.6 Evaluation

At the outset of this work, the nature of users' resilience within the context of HCI was not well understood. While limited work in this area did exist, we possessed at best an incomplete and fragmented picture concerning what types of strategies exist, how and why these strategies worked, and how we could move towards the application of resilience within the context of HCI. The work described in this thesis represents concrete progress towards an improved understanding regarding each of these questions, and in contributing a significantly expanded corpus of data and new empirically-derived theoretical insights, establishes a firm foundation to inform and support future investigation.

Based on the work conducted here, we now have an enriched theoretical vocabulary for identifying, classifying and grouping related strategies, in the form of

the refined and expanded categorisation scheme detailed in Chapter 5. We furthermore have a clearer grasp on the nature of complex cases of resilience in particular, in the form of our introduction of the notion of compound strategies. Building upon this, in Chapter 7, we present an empirically-informed conceptual framework which enables us to unpack and deconstruct these compound strategies, providing us with a new way to analyse strategies in depth and articulate the motivations and mechanisms that underpin them; rather than classifying compound strategies in a 'best-fit' manner, this allows us to break them down and analyse their constituent motivations, intentions, actions and mechanisms, providing increased insight and analytical power to compare different strategy implementations.

We have validated this theoretical work by establishing and executing novel specialised studies for the investigation of resilience (as described in Chapters 4, 6 and 8), and in so doing, provide a practical contribution towards the future study of resilience strategies, both in the form of the expanded pool of data we contribute, and in terms of practice-informed methodological guidance. Prior to the outset of the practical work described in this chapter, we also conducted an expansive literature review spanning a variety of topics and disciplines both within and extending beyond the conventional HCI literature, in order to present a broad overview which synthesises and integrates this disparate collection of concepts.

While the theoretical frameworks developed within this thesis (Chapters 5 and 7) each serve to independently inform analyses of resilience strategies, they can be combined, as demonstrated in Chapters 8 and 9, to simultaneously explore the breadth and depth of a set of observed instances of resilience. Furthermore, in cases of particular interest, our framework for the deconstruction of compound strategies can not only structure the articulation of motivations, intentions, actions and mechanisms within a strategy, but these individual elements themselves can now be considered. This may take the form of considering each in relative isolation, or, as we discussed, exploring the relationships and dependencies that exist within a compound strategy.

Looking forward, we note there are a number of ways in which the insights obtained throughout the course of this work can be applied, both in terms of informing future investigations, but also as a first step to realising applications in a HCI design sense. Before discussing these however, we first reflect upon some of our perceived limitations in terms of the work undertaken here.

9.6.1 Limitations of This Work

While the work described in this thesis demonstrates a tangible progression in terms of investigations targeted at resilience strategies, and presents a number of useful contributions to the field, we acknowledge a number of limitations here.

The strength and validity of empirically-derived theory rests on the strength of the data informing that theory. To that end, while the work presented in this thesis harnesses a combination of self-report and controlled study approaches (themselves presenting limitations as discussed in 4.7, 6.5 and 8.6.4.) and builds upon a broader and larger range of strategies than that available before, the quantity of cases collected and examined, when compared to an analogous topic such as error, could further benefit from being expanded. To enhance the foundation of work addressing resilience strategies, a broader variety of refined and more numerous investigations into resilience would benefit the field, a topic we reconsider in our discussion of potential future avenues for investigation presented in 9.4.2.

Additionally, while we have attempted to gather as broad a variety of strategies as possible, the types of strategies observed are ultimately constrained by the spaces (i.e. in terms of possible actions/procedures or available resources) within which they occur. That is to say, we are unlikely to possess a fully comprehensive view of all the ways an individual can perform resiliently in a given situation, as unexampled events in contexts beyond those we investigated may generate additional means to achieve resilience. Therefore, the manifestations of resilience we have observed, even repeatedly, across our investigations may not represent the ‘optimal’ means by which one could achieve resilience in such a position.

Stemming from this also, a further consideration, as we identified relatively early in this work (discussed in 2.3.8), is that where resilience applies at an individual-strategy level, resilience at a broader sociotechnical system or systems level can in some cases actually be eroded. While this 'higher up the chain' resilience falls beyond the individual-strategy scope of the current thesis, designers of interventions that assist or accommodate resilience must remain mindful for the potential for this to occur, a consideration which requires further work to explore.

A further potential limitation of this work is its breadth of scope, and from a HCI perspective, its tendency to consider phenomena and gather data that extend beyond the remit of the use of technology, such as our investigations into the use of 'everyday' resilience strategies as presented in Chapter 6. With such a broad scope, the propensity for this work to apply in the sense of concrete HCI applications is arguably compromised, in contrast to the types of insights that may have been delivered by maintaining a closer focus on technology-specific tasks and settings.

At the same time however, upon looking to analyse the strategies we observed during our initial study, it became apparent that we lacked a broad foundational account upon which to build an investigation into resilience strategies. Given the relative immaturity of work into the topic, and its innately interdisciplinary nature, we felt that to confine our work to focus only on resilience strategies purely within the context of interactions with technology would be an arbitrary restriction. Were we to do so, we would potentially significantly constrain the data available to inform our investigations, and this could diminish the comprehensiveness of our findings. In some cases, 'everyday' strategies may accommodate a wider array of possibilities than their counterparts more closely aligned to HCI and the use of interactive technologies, an example of which would be the way people appropriate items, with available resources for appropriation potentially being more limited in the context of technical systems. However, if for example we discover factors that influence the efficacy of appropriation outside of a narrow HCI context, this could introduce potentially transferable observations in ways that would otherwise be difficult to envision when thinking only within the

scope of the discipline. The notion of transferability works both ways as well, in that if our findings are not tied to the domain, the insights we gain are more readily available to be transferred to tasks and circumstances beyond the confines of interactions with technology.

Another potential limitation of this work, stemming from the broad scope we covered, as well as the relative infancy of pre-existing work specifically addressing this topic, would be the limited extent to which our findings can directly be translated into concrete application in terms of HCI design at this stage. During the very early conduct of the work described in this thesis, we initially hoped to generate output that could inform HCI practitioners today in a grounded and tangible manner. From assessing the existing work specifically targeting resilience at an individual level however, the work described in this thesis was, necessarily, more theoretical than originally envisaged. Consequently, the precise manner in which our empirically derived theory can be leveraged to inform design is a subject that would benefit substantially further work, however as discussed later, we do identify and present potential future avenues for this in the discussion following and consider how some of our insights can already inform future investigation and potentially be leveraged to guide aspects of design.

While we originally anticipated directing more effort towards the frontline application of resilience, the realisation that previous foundational work was limited, and the many unanswered questions surrounding the implementation of resilience for frontline operators, forced us to reconsider what would be an appropriate scope for our contribution. In order to be able to translate resilience principles into a useful and concrete way of informing design, we must first possess a rich understanding of a theory base or particular type of behaviour. We soon realised that it is only by enriching our conceptual understanding that we would be able to develop such knowledge, which can later be leveraged in a way where it becomes applicable to design. Therefore, one arguable oversight early in this work (motivating our initial study) was to attempt to investigate resilience in a fine-grained level of detail without first establishing a solid foundation upon which to base this work.

Ultimately, to work towards solutions without firm basis in foundational theory is problematic, and this work has instead gone in the direction of 'laying the groundwork' in order primarily to inform future studies into how these concepts may affect the sharp-end of HCI.

While we have yet to fully-form a mature theoretical framework suitable for immediate and direct design interventions, that is not to say that some of the insights yielded throughout the course of this work cannot be applied to inform current practice in certain contexts. Below, we present a forward-looking discussion on how we believe an increased comprehension of resilience strategies, as provided by this work, could inform further study, and ultimately in time translate into frontline HCI application.

9.6.2 Potential Avenues for Future Investigation

While we have made progress in a number of areas; in addressing our intended aims and research questions, building increased understanding concerning what resilience strategies are, what different types exist and even how they can be analysed, we consider that potentially this is only just the beginning. The current picture with regards to resilience in the context of HCI, as presented in this thesis, provides fertile ground for future investigation.

Turning initially to the collection of further accounts of strategy use, we see one potentially valuable avenue for progressing the work described in Chapter 6, the approach of using diary studies to elicit strategies. While we have expanded the corpus of strategy accounts significantly, future work investigating resilience in HCI may benefit from continuing with this activity and collecting new material for analysis, specifically in highly specialised domains. One way in which the approach of self-report collection through diary studies could be taken forward would be in the use of a mobile application, or 'app', to collect strategy accounts.

Such an application could have a number of inherent advantages over a paper format diary; it could be distributed to a vast sample with relative ease, regardless of

geographical location, it could leverage existing technology which many people routinely carry with them (thus negating the need to remember to carry a separate physical diary) and it could incorporate media, such as photo or video capture, to supplement text accounts with rich contextual information. While not reported here, this proposed approach of designing such an 'app' represents one strand of work we have already begun to explore and indeed develop during the course of this project.

Another approach for the further collection of strategy data might be in situated observations or workplace analyses. While we did not have the opportunity to conduct such an exercise first-hand, we were able to incorporate a number of cases provided by a colleague who had adopted this approach in their conduct of a separate investigation (as noted in 5.4). This approach would represent another way to obtain detailed examples of real world strategy use, albeit at a relatively high cost in terms of the commitment of resources and manpower. One clear advantage such an approach would have however, would be the ability to explore resilience in depth and in a specific domain or setting, which may be useful in any future investigations with a more constrained scope, for example focusing on control rooms or other such settings.

Our final study, presented in Chapter 8, represented a preliminary step towards the notion of establishing predictive power in the context of resilience strategies, which would indeed be a valuable step in the continued investigation of resilience. One potential approach for doing so would be to consult focused investigations of resilience strategies to inform the establishment of a set of prevalent potential associations between threats and challenges, and corresponding strategies, and to evaluate and formalise these through the use of controlled studies. While we do not yet possess a sufficiently established foundation to fully achieve these ends at this time, the work presented in this chapter and throughout the thesis moves us towards such a position. Ultimately, if a paradigm can be developed whereby we are able to isolate and operationalise certain resilience phenomena, this could yield new insights that would help bridge the gap between evaluative analysis and design implementation.

If we were to possess a comprehensive and approachable mapping between threats or disturbances and corresponding resilient interventions, this could represent a useful resource for designers of technical and sociotechnical systems. Where issues are anticipated or encountered, design interventions to accommodate for strategies and behaviours to mitigate such threats could be identified. Conversely, when conducting an analysis of performance, if resilience strategies are observed, these could be traced-back to help identify potential flaws or challenges in the design of a system (as is further considered in the discussion following in 9.4.3). This very much represents an envisaged rather than current state of understanding, but we would assert, represents a potentially valuable goal for researchers looking to better understand the resilience of individuals.

Finally, we would welcome further research that utilises the categorisation scheme and conceptual framework we have developed here, particularly in additional tasks and settings, either to further validate it or indeed refine and develop it, should newly encountered resilience strategies justify this. While we consider both of these theoretical outputs to be at a level of maturity where we are confident in their utility as they stand, both could potentially benefit from further refinement, as well as further investigation or consideration as to how best to practically apply this work to inform future design.

9.6.3 Potential Avenues for Application

As we discussed above in 9.4.1, the work presented in this thesis is may not yet be in a format fully accessible to the majority of HCI practitioners, for immediate concrete implementation in the designs of current general systems. However, in cases where resilience is targeted as an explicit design consideration (for example, this may be warranted in certain safety critical areas), we believe that the work here could still be leveraged, to inform both the assessment and evaluation of current or proposed systems and interactions, and to a more limited degree, in terms of design

as well. Future work could very much serve to enhance the applicability of the insights gained here, in order to 'smooth the flow' towards concrete design guidance.

With regards to the assessment or evaluation of systems, our work demonstrates firstly how information on resilience strategy use can be gathered. The two broad approaches we present first-hand include self-reporting in the form of a diary study, and controlled laboratory studies. The former of these would require only limited adaptation in order to potentially be applied across a range of tasks or settings, and could indeed be targeted to specific tasks, systems or environments if desired. While the establishment of a controlled laboratory study may not be feasible in many cases, with some adaptation, our approach could inform data collection through observation or task analysis in an existing task environment, or indeed in a 'user testing' type paradigm for systems in development.

Assuming a record of resilience strategy use is compiled, through either the above or potentially other means, the work included in this thesis offers two 'lenses' to support analysis of resilience cases, in the form of the categorisation scheme for establishing the variety and breath of resilience, and the framework for the deconstruction of compound strategies, which could facilitate more in-depth analysis of key cases where required. By conducting an analysis of existing or prospective resilience strategies, HCI practitioners would have increased insights into actual real-world operations (as opposed to envisioned or anticipated practice) and could use this knowledge to identify frailties or opportunities in interactions. The articulation of such frailties or opportunities could also be a worthwhile consideration in A-B comparisons between current and proposed or altered systems or scenarios, an undertaking which although relatively resource intensive, might identify potential issues and threats which could be difficult to elucidate by other means.

Returning to the question of how an increased understanding of resilience strategies *per se* can inform design, we perceive there to be two broad ways in which resilience principles can be incorporated into design. Should the system designer be mindful of resilience strategies and envisage the potential for strategies to be utilised in their designs, they may wish to provide direct support to facilitate this. This could

take the form of designing cues or reminders into interfaces, incorporating or supporting the use of checks and checklists at key points in tasks, or affording users access to informational artefacts (or the ability to create such) where deemed likely to be required. Interventions such as these represent the implementation of design that is informed by resilience strategies, and if such an approach were to be adopted, the categorisation scheme we provide in Chapter 5 could prove useful for designers in describing the space and nature of potential resilience strategies that users might implement during the course of their interactions.

One of the innate challenges of resilience however is its propensity to emerge outside of the design envelope. That is to say, however a system is implemented, users will likely compose workarounds and resilience strategies that are unforeseen by designers. The paradox of how designers may 'design for the unexpected', remains an innately challenging problem (Makri, Blandford, Woods, Sharples & Maxwell, 2014). There are however some ways in which designers, again mindful of resilience strategies, may not necessarily implement or directly support potential strategies they identify, but instead generate designs that provide the space to accommodate for users' own resilience strategies. One example of such a case would be 'designing for appropriation' (Dix, 2007) as discussed in 3.4.2, whereby user interface elements could be incorporated into an interface that serve no predefined purpose, other than to be appropriated by users, accommodating the creation of improvised and on-the-fly strategies in a similar manner to the 'user configured cueing' option present in our initial study (Chapter 4).

9.7 Closing Remarks

The study of resilience within the context of Human Computer Interaction represents a challenging endeavour. Indeed, given the constantly evolving nature of technology, the pace at which new avenues arise for the study HCI is equally relentless. These factors may dissuade some from the study of resilience in favour of topics that more obviously align with current trends or new directions in technology.

However, from our work in this area, we have seen first-hand how resilience transcends specific technological systems and if better understood, could make a positive contribution to all manner of systems, both technical and sociotechnical, across all manner of contexts and settings. The innate tendency for users to adapt their practice, environments and resources, persists across all manner of interactions, and will thus remain a facet of the discipline that merits careful consideration owing to its potential broad impact and transferability.

While designing for resilience could potentially be considered as a 'marginal gains' or indeed resource-intensive exercise, our work here however has illustrated how resilience strategies are more commonplace that one might imagine, however the nature in which they're embedded in task performance can make them difficult to identify or articulate. The importance and potential impact of resilience strategies is not to be understated too, occurring as they do in safety critical contexts such as healthcare and aviation, in which resilient strategies will have prevented incalculable harm and saved lives time and time again.

Crucially however, the use of resilience strategies has yet to be subjected to significant investigative scrutiny in a HCI context. We hope that the work in this thesis can inspire and support the continued study of these strategies, and move us toward realising the potential opportunities in terms of improving safety and efficiency across all manner of systems, task and settings.

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Appendix A1: Training and Instructions

TRAINING & INSTRUCTIONS: **Exploring the Effectiveness of Different Cueing Implementations: User Configured versus Preconfigured Cues**

Please ensure you have read and understand all this information and completed the task provided before proceeding to next part of the study.

In this task, you are assuming the role of a technician who is dispensing medication. Your role involves inputting requested medications into an onscreen form, where necessary, performing some simple calculations associated with providing the medication. You will also be asked to double-check some calculations in a secondary task.

The medication you are setting up involves *infusion* (using a pump to administer medication in fluid form) and along with the name/type of a medication, you will be requested to supply 3 values:

- **VTBI**: (Volume To Be Infused): The quantity of medication required
- **Rate**: The speed at which the medication is administered
- **Duration**: The time taken to administer the medication

In some cases, all of these values will be provided for you. However in other cases, you will need to calculate one of these values from the remaining two values. This can be done as follows:

- To calculate the **VTBI** from the rate and duration, **multiply the rate by the duration**
- To calculate the **Rate** from the VTBI and duration, **divide the VTBI by the duration**
- To calculate the **Duration** from the rate and the VTBI, **divide the VTBI by the rate**

For example, an infusion at a rate of 5ml/min over a duration of 20 minutes would have a volume (VTBI) of 100ml. An infusion of 200ml over a duration of 50 minutes would be at a rate of 4ml/minute.
And an infusion of 120ml at a rate of 10 ml per minute would take 12 minutes.

How to enter this information into the system (*Primary task*)

You will be provided with a paper 'green' slip containing information on the drugs and values which need to be entered into the system. It will list a number of 'cases', which each look like this:

Drug	**Type**	**VTBI** *(ml)*	**Rate** *(ml/min)*	**Duration** *(min)*
Colbine	ASM	120	10	12
Duprol	ASP	200	25	
Propex (0.5)	ASM		10	20

Let's work through the above example, using the onscreen training screen and following instructions.

First, locate the drug name in the 'Select Drug' section [1]. The drug name will be in one of the three drop-down boxes, you can determine which using the 'type' column. Be sure to select the exact drug required. Confirm your choice by clicking the *Enter Drug* button [2].

Next, in the 'Dosage' section, enter the three values previously described; the *VTBI, Rate* & *Duration*. If one of these values is not available, please calculate the missing value as described previously. Please perform each of these calculations one at a time, as you go along (as opposed to all at once).

- Enter the *VTBI* [3] and click *Enter* to confirm [4]
- Enter the *Rate* [5] and click *Enter* to confirm [6]
- Enter the *Duration* [7] and click *Enter* to confirm [8]

VTBI = Rate x Duration
Rate = VTBI / Duration
Duration = VTBI / Rate

Then click *Add* [9] to add these values to your current selection, which is displayed in the box on the right [10]. Double check the information entered is correct (if it is not, you can use the remove button to remove the highlighted entry- please then re-enter the drug as described above).

Assuming the values are correct, repeat the above process starting from step [1] until each of the three drugs in the case are entered. Once the full case has been entered, confirm by pressing the *Confirm* button [11]. In the actual task, you will be given several cases- at this point, the current selection box [10] would clear and you would continue to enter the next case, repeating the process from step [1]. The task automatically ends after you have completed entering the final case.

Checking provided calculations (*Secondary task*)

In situations where important calculations need to be made, it is common that such calculations are double checked by a second person to verify that they are correct.

At certain points during the above task, a message will appear on screen requesting for you to check some calculations, which will be provided on the 'checkered pattern' paper slip, and will look like this:

Drug	Type	VTBI	Rate	Time	CHECK
Mycol	ASM	120	6	20	
Glytine	Misc	240	6	40	
Propox (5.0)	ASM	300	15	30	

When you are requested to check a case on this slip, please momentarily stop the primary task, and check over the provided calculations immediately.

These calculations use the same formula provided above, where VTBI = Rate x Duration.

Please indicate whether each row is correct or incorrect by providing a tick or a cross in the corresponding *Check* box to the right. When you have checked all the calculations for the given case, please return to the primary task and resume from where you left off.

While the names and dosages of the drugs used in this task are entirely fictitious and your performance has no implications in terms of patient safety, please try to be as accurate as possible with your inputs.

When you are ready to continue onto the task, please click the *Proceed* button to begin.

Appendix A2: Values to Enter into System

CASE ONE

Drug	Type	VTBI	Rate	Time	CHECK
Mycol	ASM	300	10	30	
Glytine	ASP	500	20	25	
Propox (5.0)	ASM	200	6	40	

Please resume with the primary 'drug setup' task

CASE TWO

Drug	Type	VTBI	Rate	Time	CHECK
Colbine	ASM	480	8	60	
Myvrole	Misc	300	5	60	
Dyphine	Misc	600	15	40	

Please resume with the primary 'drug setup' task

CASE THREE

Drug	Type	VTBI	Rate	Time	CHECK
Phrospone (25)	ASM	360	6	50	
Trovol	ASM	360	12	30	
Propox (0.5)	ASM	600	8	75	

Please resume with the primary 'drug setup' task

CASE FOUR

Drug	Type	VTBI	Rate	Time	CHECK
Duprol	ASP	120	12	10	
Chlopol	Misc	60	3	20	
Phospine	Misc	160	8	20	

Please resume with the primary 'drug setup' task

Appendix A3: Values to Check (Distractor Task)

CASE 1

Drug	**Type**	**VTBI** *(ml)*	**Rate** *(ml/min)*	**Duration** *(min)*
Prancol (15)	ASP	120	10	12
Dyphine	Misc	200	25	
Phesphene	ASP		10	20

CASE 2

Drug	**Type**	**VTBI** *(ml)*	**Rate** *(ml/min)*	**Duration** *(min)*
Microle	Misc	300	5	60
Phospine	ASP	300	10	
Prancol (1.5)	ASP	150	5	

CASE 3

Drug	**Type**	**VTBI** *(ml)*	**Rate** *(ml/min)*	**Duration** *(min)*
Phrospone (25)	ASM	100		20
Trovol	ASM	75	2.5	30
Chlopol	Misc	75	5	

Appendix B1: Strategy Accounts Used in Workshop

CATEGORY	SUBCATEGORY	STRATEGY DESCRIPTION
Cue Creation		Nurse leave sample stickers on patients doors
(physical, social, informational)		Reminder to cite things properly when writing a report
		If I forgot to take my pill and remember it during the day, I set myself a reminder for the time I'm due to get home
		Spatial layout of anticoagulant acting as cue for patient to remember to use it before starting dialysis
		Burglar alarm (flipdown) - Close cover + note "no alarm today" revealed to stop habit of switching on
		Even though I have a reminder on my phone, I tend to remember without it - I use it just in case
		Keep my pills in the make up bag so I remember to take them every morning
		Pilots writing in manual "I will forget this step"
		I use multiple reminders every 15 minus until I take the pill and switch off the reminder
		I use the phone reminder as more of a back-up: I generally have taken the pill by the time I see the reminder
		I tell my boyfriend once I've taken it and sometimes he'll ask if I've taken it yet and this will help me remember (cue self-check)
		Keys on belt act as a cue- silence of new jingling
		The use of a while baton to remind people to turn off equiptment at the end of the day. An individual would take the baton at the beginning of the day and pass it to a colleague if they needed to leave early
Pre-emptive Separation & Disambiguation		Save some files in YYYY-MM-DD format, sorting by name => chronological order
		One hand for trolley and one hand for doing hygene things / CAT
		Having separate trays for going on dialysis and for coming off
		Disambiguating suitcases
		Different key fobs to separate very similar keys
		Keys are positioned on key ring on different rings so they fall at different levels so house key is easy to pick without even looking, office is at top
Appropriation / Substitution (Reactive)		I type in online forms… one has v. small font, I compose in another & paste it in
		Scissors broke so I opened parcel with a sharp pen
		Typing words into a word form so: -doesn't log you out (web) -Just nicer. See what you're doing.
		Taking a photo to quickly and accurately capture information
		Substituting info about miles to London to minutes to somewhere else
Checking (Observing Steps or States)	Pre-commitment	Roller clamp avoid opening until end of procedure
		Asked partner to check if they had zoo membership card before setting off
		Carer double-checking setup of machine before patient starts treatment
	Parallel	Over shoulder
	Post	Taking all pills from the box to count them to check if todays pill was taken
		Taking the pill in the morning and then double-checking in the evening if it was taken
Managing resource availability (Prospectively)		Keys always hooked on belt so don't go out without them as I never go out without trousers
(Equiptment? Time? Cognition?)		Deliberately creating many redundant backups
		Emergency cash in car / spare coats in car
		Having spare supplies at hand, e.g. if syringe breaks
		Pound in swimming bag side pocket so always there (and handy) when need for locker
		No phone charger, low battery on phone one evening: turn off overnight to preserve some battery for next day
		Getting partner to also set a 'back up' alarm on phone
		Giving neighbour key to house, if emergency happens during dialysis and patient is alone at home
		Leaving some screenwash in container so I don't run out
		I take my pill in the morning because I have the whole day in case I forget (my pills let me be up to 12 hours late)
		On a producton line assembling a series of components in advance to buffer enexpected issues in fitting parts
Reinforcement		Extra thick socks when wearing in new boots
		Calculating a result twice => error = process problem
		Running vascaline nipples
Interruption / Attention		Band writing requirement for black jelly babies into contract
		Packing bag downstairs - recognised risk of forgetting medication. Immediately went upstairs to get meds first, then resumed packing
		Using a pink phone cover to avoid missing a black phone
		Cues to support attention (vs memory)
		Momentarily deferring interruptions
		Pilots after a transatlantic flight, performing "fake" tasks prior to landing to maintain/improve attention/awareness
Memory		Lady with dyslexia reading her notebook for phone number
Routine adjustment (longer term?)		Loading a musket - banging into the ground instead of using ramrod
		Used to take pills in the evening, but because the routine varied too much, she started taking them in the morning
		Allowing more time to do something to not miss a step
		I take it the minute I wake up and always have water by my bed
		Reset VTBI counters on infusion pumps at midnight
Manging the complexity / simplifying the situation (temporarily?)		Human error space invaded game - move ship to edge so no chance of being hit
		In A&E emegency overdose of drug to stabalise - do in time to save life then can fix overdose later
Rituals & Superstition		Using an oversized lock box because no one knew why and didn't feel confident
		Walking under a ladder
Misc / uncategorised		Making an infusion device case out of a deliberately weak material so that if it was dropped it is apparent
		Marking on the patient that a guide wire has been removed. Chech in the futuree possible

Appendix B2: Strategy Accounts Used in First Validation

Validation	Strategy Description
First	I have moved into a new flat and have 2 keys which are indistinguishable. I have moved one key next to my keychain so that i can identify which is which.
First	On one of the online forms at work, a textbox is very small and hard to read. I type into a larger text box and copy across when finished.
First	Work- I have purchased extra chargers for electronic devices which I keep with me at all times. This is most important for my mobile phone.
First	At work, I get assigned 'footprints'. On receiving, I use outlook's colours to mark the footprint as relevant, not relevant or urgent. I then use the 'flag' system in Excel as follows: flag = to-do, ticked = script written (follow up on next Monday), blank = no action needed. This combination covers all scenarios and makes it easy to see what needs to be done.
First	Work/home- I leave windows open on my desktop to ensure I do not forget to read/act on the contents of windows. My PC at home is usually left on hibernate so as to preserve the windows.
First	Wrote a to-do list for the week, so as not to forget to do any important tasks.
First	As a trend I make use of sticky notes on my laptop and iPhone, writing ideas, movies I have to watch, errands I have to run.
First	Leave letter that I need to scan and email next to laptop so I don't forget to do it. Conscious intentional.
First	Placing software toolbars so to remind you to use them rather than going through 'edit' etc.
First	At home working and on the move- Calendar syncing does not work. To carry out my job effectively I need access to accurate calendar wherever I am. On blackberry and iPhone and MacBook Air as sync doesn't work I take a photo once a week of the calendar on my mac, and refer to the photo when need to look at dates.
First	My mum cant hear the business phone ring from the kitchen. So she uses baby monitors in study and kitchen so she can hear the phone go and just about make it there in time to answer it.
First	After setting alarm on my phone, asked partner to set up a 'back-up alarm' on his own phone, in case mine didn't work for some reason.
First	Before leaving to go to the zoo, asked partner if he had his membership card, as would have been a waste of time driving there if not.
First	Our timer for the hot water tanks is broken so we rely on manually switching on/off when we need hot water. Its easy to forget to turn them off after use, because they are in a cupboard. We leave the cupboard door open when switches are on- to provide a cue to reduce the risk of forgetting.
First	Editing and saving a document on laptop, which I considered to be important. As opposed to just saving the one copy or making one backup, I saved several copies in a few different places. Redundant copies reduced risk of data loss and made it easier to locate in future.
First	Went to a few music concerts- noticed drummers frequently have a 'pot' with several spare drum sticks
First	Upon facing an interruption, users would momentarily ignore or defer the interruption to ensure they were pausing their primary task at a 'meaningful' place (e.g. if they were in the process of performing a calculation, they would quickly finish and record the result before diverting thier attention toward the interrupting task).
First	Tracking progression through an onscreen data entry task by checking-off values on the piece of paper in front of them
First	Temporarily inputting an arbitrary value into a field upon interruption, to indicate where to resume from after the interruption had passed
First	Re-structuring the sequence of data entry in a form to a sequence which is less demanding on working memory
Second	Was in a lecture- students were told slides would not be available after, several people subsequently captured them using their camera phones
Second	I had several small things to do the next day which i had previously deferred. To make sure I didn't forget them, I listed them in the notes app on my Ipad.
Second	Was driving the car when I remembered I had an important, time critical email to send. I didnt want to stop the car or forget to compose it, so I tapped 'email' and 'compose' on my phone so when I parked up and looked at my phone next, I would have a visual cue to reminder me (an empty email).
Second	Used quiet music and in-ear headphones to drown out distracting noise when trying to work on a busy train
Second	Flagged a number of important emails which i need to respond to soon (eg electricity bill, family member email etc). Reduces threat of them being forgotten and not getting replied to.
Second	Took a hot baking tray out of the oven. We usually stand these on the hob as our surfaces can be damaged by heat- but the hob was full with pans. Took a bar/beer mat, put it on spare surface and tray on there to prevent directly putting tray on surface.
Second	Had forgotten phone charger when travelling- only realised in the evening just before bed. Phone had low battery so I turned it off to save some battery for the next day. Threat recognised was that I may have no phone battery left the next day and would subsequently not be reachable
Second	Was halfway through packing bag downstairs when I realised there was quite a risk i'd forget my medication (its not routine and it is stored out of the way). I immediately went upstairs to pack it, changing what would have been the packing order, to make sure it wasnt forgotten by the time I got upstairs.
Second	My scissors broke so I opened tough parcel with a sharp pen
Second	Went to printers and didn't have memory stick so sent email to myself, opened it on phone to show printer guy, then sent him the email with file.
Second	After making some sandwiches to take into work for lunch, I put them by the front door so I wouldn't leave without them.
Second	At work. Remembered I hadn't replied to a message from a friend, sent a few days ago. Wrote her initial on my hand to remind me to do so when I got home.
Second	Sitting on sofa with laptop. I know that when I shift position while holding the laptop I get a static shock, so now I put it down before i move + pick it up again afterwards. This is now an absent-minded/routine action.
Second	Report write-up (citation) - It is my own strategy - I always write a piece of paper, put in on my desk to remind me to do the "proper citation" for my MPhil write-up - I feel this is me being very intentional - This is happening every day at my home - I dont think I do this because I forget to do so, but because I somehow try to force myself into doing so.
Second	I always forget about this diary - So I put it on my laptop every day when I finish working so that I remember it the day after - This way really helped me to remember it everyday - I think this is one of my regular routines - This is intentional.
Second	Instead of a task list, I send emails to myself. These are then put into folders if they are not urgent. The folders correspond to different areas of my job e.g. when I work on 'testing', I open the testing folder which contains a list of tasks.
Second	I only ever put items such as key/oyster card & wallet in my bag or on one table. This prevents losing them or forgetting as I only have to check one place.
Second	I store photos in folders with names containing dates as YYYY-MM-DD - this means sorting by name orders the folders chronologically.
Second	I always get a colleague to proof-read any external emails regardless of size/importance.
Second	My phone does not have the facility to mark SMS messages as unread. As such, I will often not read them until I know I have time to respond.
Second	When I am out and need to copy something, I will instead take a photo. As I regularly check my photos, this is quite reliable.

Second	I record all errors on a spreadsheet (errors are reported daily and I store no. of errors for each area). I colour the cells based on any action I have taken. E.g. blank - no action, green - immediate fix / should be clear tomorrow, purple - should be fixed next week, blue - no action required, grey - reported in error, red - have contacted third party to fix the error.
Second	When out and sitting down, I keep my bag between my legs so I do not forget to take it when leaving.
Second	I have created automated procedures for as many aspects of my work as possible. This eliminates human error. In these procedures (usually run in MS Excel) I include checks which are boxes which turn green or red. If any boxes turn red, the automated procedure will not work and the issue should be investigated. T
Second	At work we have public folders where some work is stored at the end of the day. This is to cover for an employee being ill. If they are, someone else has access to their work and can continue in their absence.
Second	Afraid of having no network (EE 3G disappears from time to time) I print screened at home (Wifi access) Google maps path to the restaurant I was supposed to meet the lady.
Second	Leave refil for car next to car keys to remind me to take it out.
Second	I go to work and plan my journeys on tfl journey planner. But because I have got to do 5 or 6 diff journeys I can't store them all and the website times out I take screenshots on my iPhone. I then also make note of journey start times in my notes on iPhone so I can quickly refer and make sure I don't miss any appts. I also do the same with postcodes so I can easily throw them in google maps if I need without dragging email up.
Second	At work the cleaning lady always takes my red bowls that belong to me that we use for popcorn. By day 5 I decided to hide them each night to stop her washing them and throwing popcorn away.
Second	I lost the diary you gave me so I completed these entries on my phone..
Second	I have to reel off card details in public quite a bit, so I usually make sure before making a phonecall that may involve paying for something, I have somewhere to go. At **** it was the private dressing room. Where I work sometimes there is a phone box just outside so I use that. It has to be somewhere where they can hear me, but passers by cant.
Second	We were going for a walk and I am currently 'wearing in' some new boots. Even though it was a hot day, I wore extra thick winter long socks to reduce the friction from the shoes and provide padding.
Second	We were in a pub garden and it was much colder than expected. We made use of spare coats which live in the boot of the car.
Second	Didnt have the time to record previous strategies thoroughly and didn't have diary on me, thus made very brief notes into the notes section of my phone· minimised the risk of them being forgotten.
Second	When users 'lose' the mouse cursor on a screen, they often do one of several things: 'shake' the mouse, rotate it in small circles, or throw into a corner so they'll know where to find it (mentioned during conference presentation at EICS)
Second	I needed to collect something from a colleague. I emailed ahead to ask if he'd be in the office tomorrow for me to collect it- or to leave it in the office this evening if not
Second	Strategically placing glasses in an easy location to grab blindly upon enering/exiting the shower
Second	I leave my alarm on my phone for 11am each day as I am up at that time, it reminds me to take vitamins and medication everyday. I also leave it by toothbrush, so usually see it while brushing teeth.
Second	After taking shower, wanted to leave extractor fan on for longer that its default timer, but didn't want to leave it on all night wasting electricity. With the fan, the light is on by default. Therefore left the bathroom door slighly ajar so could see light on when walking past
Second	Got home and realised we had taken the nectar card with us (we usually leave it in the car as we virtually only use it for petrol). Left it propped up in an obvious location by the front door to ensure it was remembered when we next went to the car. We do the same thing with our 'bags for life' after bringing shopping in so I regard this as routine- largely subconscious.

Appendix C1: Instructions for Pilot Study

Introduction

We frequently use a variety of little strategies to reduce risks or errors in every day life:- things like setting an alarm on a mobile phone to act as a reminder, leaving an umbrella by the front door to make sure its not forgotten on the way out, or double-checking the traffic situation to find the best route for a journey before heading off. Equally, people apply these ideas to technology- flagging important emails, emailing themselves weblinks or files which will be required later, or even supplementing device controls with improvised notes (e.g. “press the green button here to make a copy ->”) etc.

Researchers have recently begun to take an active interest in how people devise and use these strategies, which we term *cognitive resilience*. The central idea around these resilient strategies or behaviours is that people pro-actively take action to reduce the risk (either in terms of occurrence or severity) of a perceived threat, risk or challenge. This may take the form of intentional, creative improvisation, coming up with a strategy for the first time- or routine, absent-minded reuse of strategies (or anything between!).

As you can appreciate, there are a very wide (practically unlimited) array of these strategies which people use in all walks of life. The following (in addition to those given above) at all examples of resilience in one way or another:

. I need to remember to meet Jane on wednesday but I don’t have my planner on me- I’ll write it on the back of my hand for now so I don’t forget.

. I mustn’t forget to reply to this important email, but I need to do something else first. I’ll resize the window and leave it in the top right corner of the screen so I don’t forget.

. These two buttons on my TV remote look very similar, I often press the wrong one accidentally. I’ll mark the one I usually want with a blob of tipp-ex to remind me and differentiate between them.

. I’ll make sure I keep the pile of scrap paper on my desk away from anything important, to make sure I don’t mix them up.

. I don’t want to get half-way through assembling these flat-pack drawers only to realise they forgot to include a part- therefore I’ll check all the parts are present before I begin.

. I frequently end up forgetting my laptop charger, so I’m going to buy a second one and keep it in the office so I don’t have to remember to bring my own.

. I need to do ‘Task X’ at work but it always takes a long time. I’ll go in early tomorrow to make sure I’m not working late to make sure I don’t miss my evening flight.

. This suitcase handle doesn’t look very sturdy, I think I’ll reinforce it before I next need to use it incase it breaks when I’m out and about.

. I know I said i’d phone home at 7pm but I don’t want to loose my train of though while I’m in the middle of writing this section. I’ll finish this off first and ring in 10 minutes or so.

Prompts

Please describe the resilient behaviour or strategy you observed. Please include:

1. Whether the behaviour/strategy was yours or someone else's
2. Time and place of occurrence (and, if applicable, the task)
3. Did it include any objects/items/artifacts, if so please describe (physical/on screen)?
4. If (yes) above, what purpose did the object/item/artefact have?
5. What was the challenge/risk/threat that this helped mitigate?
6. Would you consider it to be creative/‘new’, or regular/routine, or somewhere between? (Used before frequently, occasionally or never?)
7. Similar to the above, would you describe this as being very intentional and deliberate, or more ‘automatic’ or absent-minded?
8. Any other details (feel free to sketch if this is easier!)

Notes

Appendix C2: Final Instructions for Diary Study

PARTICIPANT INFORMATION: An Investigation into Everyday Resilience Strategies

We would like to invite you to take part in a research study. Before you decide whether you would like to take part it is important that you understand why the research is being done and what it would involve for you. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information.

What is the purpose of the study?

We frequently use a variety of strategies to reduce risks or errors in every day life:- things like setting an alarm on a mobile phone to act as a reminder, leaving an umbrella by the front door to make sure its not forgotten on the way out, or double-checking the traffic situation to find the best route for a journey before heading off. Equally, people apply these ideas to technology- flagging important emails, emailing themselves weblinks or files which will be required later, or even supplementing device controls with improvised notes (e.g. "press the green button here to make a copy ->") etc.

This study is aiming to help us better understand these strategies, which are the result of what researchers refer to as *cognitive resilience*. The intention is to collect a wide variety of strategies to analyse, which will help us understand the range of resilient behaviours which individuals undertake. This will help contribute towards an emerging research area, with the ultimate intention being to generate systems and interfaces which better accommodate and facilitate resilient strategies.

The study is being conducted by Jonathan Day as part of his PhD research project, which is being undertaken at City University, London. The PhD research is being conducted as part of the EPSRC-funded CHI+MED project (www.chi-med.ac.uk).

Why have I been invited?

The sample for this study is intended to reflect the general population and as such, the study is open to any individuals above the age of 18 years, regardless of gender, occupation, level of experience or prior knowledge etc.

Do I have to take part?

Participation in the project is voluntary, and you can choose not to participate in part or all of the project. You can withdraw at any stage of the project without being penalised or disadvantaged in any way. It is up to you to decide whether or not to take part. If you do decide to take part you will be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason.

What will happen if I take part?

You will be asked to read and sign a consent form indicating that you understand and are happy to complete the task. You will then be given a diary, within which you'll be asked to record any examples of a resilient strategy which you encounter throughout the duration of the study (which will be a period of two weeks). Upon completion of the diary study period, you'll be asked to return the diary. Based on the content of the diary, you may subsequently be asked to attend a brief and informal interview to clarify on or elaborate on the content of the diary at a mutually convenient time and location in the weeks immediately following the diary study period.

What do I have to do?

The central idea around resilient strategies or behaviours is that people pro-actively take action to reduce the likely impact (either in terms of occurrence or severity) of a perceived threat, risk or challenge. This may take the form of intentional and creative improvisation (coming up with a strategy for the first time), or routine and absent-minded reuse of strategies, or anything between! For this task you are simply asked to reflect on these strategies as you go about your normal business, and to record and describe these strategies in the diary provided where you encounter them- either when you use them yourself or when you see or learn about others using them.

When should I record strategies?

Preferably, at the time they are used/observed, or as soon as possible after, as this will reduce the risk of things being forgotten- but we understand this may not always be possible (e.g. when at work, or just in the middle of something). If you're unable to record a strategy at or around the time it occurs, please do still record the strategy from memory.

How many strategies should I write?

As many as you can, however this will of course vary depending on how many you observe or notice. We don't know how many strategies you may encounter during a day, it is likely to depend on any number of variables, so there is no such thing as writing 'too many' or 'too few' for the purpose of this study.

What should I write?

This is a 'free form' diary study and as such you can write as much or as little as you wish to, or are able to, at the time. However there are some aspects of resilient strategy use which we find particularly interesting, and we hope you'll use the following list of 'prompts' to guide your descriptions of strategies wherever applicable/possible:

1. Was the behaviour/strategy your own or someone else's?
2. The time and place of occurrence (and, if applicable, the task)
3. Did it include any objects/items/artifacts, if so please describe (physical/on screen)?
4. If (yes) above, what purpose did the object/item/artifact have?
5. What was the challenge/risk/threat that this helped mitigate?
6. Would you consider it to be creative/'new', or regular/routine, or somewhere between? (Used before frequently, occasionally or never?)
7. Similar to the above, would you describe this as being very intentional/conscious, or more 'automatic' /absent-minded?
8. Any other details which you feel are interesting or relevant

Note the above list is also presented in your diary for your convenience.

Here is one potential example of a complete entry (note that the time & place of strategy use isn't available, but the rest of it can be reported and is still very useful!)

Saturday evening: Was talking to a friend who had just come back from traveling abroad. She told me she always carries a couple of high-value banknotes tucked in her sock, as a backup incase she should be pick-pocketed or loose her purse. She read this was a good idea from an internet forum. It has become routine when she's in high-risk areas.

Here is another:

Monday 8:40am on train to work: Remembered I must call a friend later today when he's out of the office. I texted myself 'call James' as a reminder, using my mobile phone. Reduced risk of forgetting. Frequently use this as its quicker than setting a proper reminder on the phone, so is something I do automatically. Note: I leave the message unread on my phone until I've completed the task, so when I glance to check my phone I can see the onscreen icon for an unread message, which tells me I still need to do something.

What if I'm not sure something is a 'proper' resilience strategy?

Please do write it anyway! The definitions of 'cognitive resilience' and 'resilience strategies' are not fully clear and are open to some level of interpretation. In fact, bringing increased clarity to the question of "what is resilience" is one of the motivations behind this study.

What if I observe an example of resilience which I am not comfortable sharing?

If, for any reason, you are not fully comfortable with disclosing something in the diary then of course please omit it. You are not asked or expected to provide any information that you are not fully comfortable with sharing.

Expenses and Payments

Upon completion of the study, you'll be paid to the value of £25 in Amazon.co.uk vouchers to compensate you for your time and thank you for your participation.

What are the possible disadvantages and risks of taking part?

There are no perceived risks or disadvantages associated with participation in this study.

What are the possible benefits of taking part?

You will be contributing to the growing body of research which helps us understand the nature of cognitive resilience, specifically the different 'types' of strategy which people employ, the motivations and underlying mechanisms of the strategies, and what makes them more or less effective. Additionally, you may gain insight into strategies and behaviours which may make you more resilient to errors, threats and problems in future.

What will happen when the research study stops?

For the duration of the research project, your data will be stored in accordance with the principles of the Data Protection Act. No personally identifiable information will be passed to third parties, or retained for beyond the duration of the project. Should this project be stopped prematurely for any reason, all associated data will be destroyed.

Will my taking part in the study be kept confidential?

Your participation in this study will be kept confidential, and the data which you provide during your participation will be de-identified and not linked to any personally identifiable information. Only researchers associated with this investigation and with the wider CHI+MED research project will have access to any of the data provided.

What will happen to results of the research study?

The findings of this study are ultimately to be included in a PhD thesis and associated documents, and findings may be published in due course within the relevant academic literature. Where published, data will not include any personal or identifiable information. You can request to be informed of any future publication by making this known to the experimenter now or later via the contact information attached below.

What will happen if I don't want to carry on with the study?

You are entirely free to withdraw from the study without an explanation or penalty now or at any time.

What if there is a problem?

If you would like to complain about any aspect of the study, City University London has established a complaints procedure via the Secretary to the University's Senate Research Ethics Committee.

To complain about the study, you need to phone 020 7040 3040. You can then ask to speak to the Secretary to Senate Research Ethics Committee and inform them that the name of the project is: *A Diary Study into Resilient Strategy Use in Everyday Life*

You could also write to the Secretary at:

[redacted]

Email: [redacted]

Who has reviewed the study? This study has been approved by City University London *School of Informatics* Research Ethics Committee

Further information and contact details:

Researcher

Jonathan Day

[redacted]

Email: [redacted]

Research Supervisor

Dr George Buchanan

[redacted]

Email: [redacted]

Thank you for taking the time to read this information sheet.

Appendix C3: Prompts Contained in Diaries

1. Was the behaviour/strategy your own or someone else's?
2. The time and place of occurrence (and, if applicable, the task)
3. Did it include any objects/items/artifacts, if so please describe (physical/onscreen)?
4. If (yes) above, what purpose did the object/item/artefact have?
5. What was the challenge/risk/threat that this helped mitigate?
6. Would you consider it to be creative/'new', or regular/routine,
or somewhere between? (Used before frequently, occasionally or never?)
7. Similar to the above, would you describe this as being very intentional/conscious,
or more 'automatic' /absent-minded?
8. Any other details which you feel are interesting or relevant

Appendix D: Strategies from Diary Study

DIARY ENTRY	FURNISS ET AL CATEGORY	REMARKS
Left keys by bedside so as not to forget them	Cue Creation	First round
Went out to shop for suits the day before I was out and not coming home, I left a spare shirt by the front door before I left to ensure I didn't forget it	Cue Creation	
Make a packed lunch to take to work on the night before, in case am running late in the morning	Cue Creation	
Take lunch out of the fridge and leave it by front door in the morning, so as not to forget to take it to work	Cue Creation	
Leave rubbish by the front door when preparing to go out so I remember to take it out when I go	Cue Creation	
Took opened bag of crisps out of cupboard and left them out on view so that we would remember to eat them before they went stale	Cue Creation	
Set alarm to wake me up for work using my phone	Cue Creation	First round
Wrote shift changes in diary to avoid forgetting	Cue Creation	First round
Text reminder to friend about the arrangements for the day	Cue Creation	First round
Put clothes out ready to change to ensure promptness	Cue Creation	First round
Used phone alarm for cooking time as no alarm on oven	Cue Creation	
Was asked to remind someone to buy something	Cue Creation	First round
Left coat in eye line in staff room to remind me to take it home	Cue Creation	
Wrote out a note to act as a reminder	Cue Creation	First round
Set several alarms on phone for the periods during the AM	Cue Creation	
Wrote list of things to do, pen & paper	Cue Creation	First round
Mental notes remembered on trigger associated (yoga class at leasure centre)	Cue Creation	
Received text reminding me to do something	Cue Creation	First round
As a trend I make use of sticky notes on my laptop and iPhone, writing ideas, movies I have to watch, errands I have to run.	Cue Creation	Used to assess 10-item scheme
Before leaving to go to the zoo, asked partner if he had his membership card, as would have been a waste of time driving there if not	Cue Creation	First round, Workshop
Timetable on poolside to remind of when lane ropes need to go out	Cue Creation	
Dads birthday- reminder in diary	Cue Creation	First round
Verbal reminder received from family	Cue Creation	First round
I always write a piece of paper, put it on my desk, to remind me to do the 'proper citation' for my MPhil write-up... I don't think I do this because I forget to do so, but because I somehow try to force myself doing so	Cue Creation	First round, Workshop
Poster reminder at work- notice for christmas party tickets	Cue Creation	
Wrote a to-do list for the week, so as not to forget to do any important tasks	Cue Creation	Used to assess 10-item scheme
Notice at work for sports hall changeovers	Cue Creation	
Placing software toolbars so to remind you to use them rather than going through 'edit' etc.	Cue Creation	Used to assess 10-item scheme
Food shopping list using pen and paper- easy to do and transport	Cue Creation	First round
Email reminder of a holiday booking sent by company	Cue Creation	
Received a couple of emails at work which I wanted to save for future reference. I used the 'follow up' flag on Microsoft Outlook to move the emails to the to-do collumn where I can find them easily.	Cue Creation	First round
To remind myself of ongoing tasks to do at work I will make a note on a post-it note and display it infront of my desk. Once the task is completed I take the post-it down. This helps me remember everything which needs to be done	Cue Creation	
Kept forgetting to call supplied about new car wing mirror so I put a reminder on my phone calender	Cue Creation	
A friend told me that she writes a to-do list on her days off work to not only remind herself of what tasks she needs to do but also to motivate her to complete them as she can cross them off once done	Cue Creation	
Housemade needs to return tent to a work colleague. She placed the tent next to the door so that she would see it before leaving the house and remember to take it to work	Cue Creation	
Putting items in a location that involves them being found several times a day- as reminders (magazine clipping in handbag)	Cue Creation	First round
Creating a (digital) notebook that is portable and updates to a variety of locations through a cloud network (mobile, evernote, computer) to reduce risk of forgetting	Cue Creation	
When I was packing a bag at home before heading off for the weekend Saturday morning, I wanted to leave my laptop charging for as long as possible but ensure I didn't forget it. Left its case at bottom of stairs as a cue/reminder.	Cue Creation	First round, Workshop
I flag any important emails that contain links to websites and logins that I use frequently, they appear in my outlook on the front page and I use them as bookmarks	Cue Creation	
Leave letter that I need to scan and email next to laptop so I don't forget to do it. Conscious intentional.	Cue Creation	Used to assess 10-item scheme
If I need to remember some items to take to work, I always accumilate them the night before and leave them by the door	Cue Creation	
From the photo I enter in a reminder app on my phone the date and time I'll be working which I set to remind me an hour before I am due to start	Cue Creation	
When attempting to memorise route in unfamiliar city, looked for graffiti to use as waypoints + took photos	Cue Creation	First round
I needed to call a nurse when we received a prescription for a certain patient. I put a post-it note on the physical side of the screen at the workstation I was working at to remind me for when it arrived	Cue Creation	
A friend of mine's birthday is at the coming weekend. I set an alarm on my phone with her name a 'bday' as the event to remind me to wish her a happy birthday	Cue Creation	

I needed to chase a stock order at work later in the day. I wrote the details on my hand to remind me later that day.	Cue Creation	
I needed to issue a blood product to a patient on one of the wards. This was not urgently needed and could wait until after my break. I sent myself a mail on the pharmacy system so that it would prompt me when I next logged in after my break	Cue Creation	
I needed to remember to put the washing machine on before I went to work. I repeated in my head "put washing on" to help me to remember	Cue Creation	
Tomorrow I need to chase up an authorisation form from a consultant for a patients medication. I wrote the details on the whiteboard opposite the staff entrance door so when I go in in the morning I will see it	Cue Creation	
The evening before I went abroad I put my passport on top of my keys and wallet so I didn't forget it.	Cue Creation	First round
I use my calendar on my phone to log events in the future e.g. helping with undergraduate teaching is something outside my usual routine so I put it in my calendar to remind me to turn up	Cue Creation	First round
I sometimes put things by my front door so I remember to take them with me when I leave the house, e.g. letter to post	Cue Creation	First round
I email tasks to myself so tht when I get home and check my emails on my computer it reminds me to do them	Cue Creation	First round
When at work I leave incoming emails unread until I have time to deal with them to ensure I don't read them and then forget them	Cue Creation	First round
When I think of something I have to do later I send myself an email, and leave it unread until I get home and have time to do it	Cue Creation	First round
I also write notes on my hand in marker pen so they don't wash off until I've done them	Cue Creation	
When I have something to do (e.g. a bill to pay) I never tidy it up (e.g. file the document away). This way I never have a tidy home until my jobs are done. It serves as a reminder and ecouragement as I do not like the mess!	Cue Creation	
I have a system of categorising emails in outlook. I use a combination of 'flags' and categories to create my own complex categories,	Cue Creation	
I leave my alarm on my phone for 11am each day as I am up at that time, it reminds me to take vitamins and medication everyday.	Cue Creation	
I also leave it by toothbrush, so usually see it while brushing teeth each morning. So sometimes I have already done it when my alarm goes off. So it's essentially a second reminder.	Cue Creation	
The night before work, I always make sure I have piles of paper etc that I need to bring, on my desk. The wall to office is see through so I always can see the piles and remember to bring them with me.	Cue Creation	First round
When I use a taxi app (hailo), it always asks me to review my driver at the end of the journey. I never have time to do this as always carrying lots of bags (hence using a taxi..) so no free hands to give them 5 stars etc. I quit the app by clicking the home button, this ensures that next time I order a cab, I have to review the previous journey first, as it saves the app on the last screen from previous journey. This acts like a reminder, as otherwise I would forget to review the drivers (and then they pick up less jobs).	Cue Creation	First round
Coded doors: text myself key combo for locked (by code) door at work, prevented forgetting the combination to door	Managing resources	
Took a spare phone charger to work knowing my phone would see more usage that normal today- to avoid flat battery resulting in being unreachable	Managing resources	
Ironed a shirt for Tuesday. Decided to iron 6 to last me until Wednesday next week to avoid ironing every day	Managing resources	
Placed a stationary order at work. I decided to order more supplied than usual based on business needs of the previous year- avoided running out of important materials	Managing resources	
Used business card to make a note to call a customer when refunded	Managing resources	First round
Habitually place phone, keys and wallet in the <same> place in order to prevent their loss or the loss of time in searching for them	Managing resources	
Work- I have purchased extra chargers for electronic devices which I keep with me at all times. This is most important for my mobile phone.	Managing resources	Used to assess 10-item scheme
Had to collect train tickets from the station using collection code. Entered the code into my calendar on my phone (better than writing on paper as I always have my phone with me)	Managing resources	
Parked in a multi-story car par. Figured I would probably end up forgetting which level I was on so I text myself the letter incase I did forget. I do this quite often but not every time as I usually do not forget.	Managing resources	
Listing all the contents of the freezer and placing this on the fridge/freezer to prevent overbuying	Managing resources	First round
To do list- on paper updated throughout day, typed up at the end of the day into evernote, synced with phone and printed for next day	Managing resources	First round
Wrote a list of frequent numbers I call several times a day and stuck these to the edge of my telephone- enables me to make calls quickly all day without having to refer to email signatures	Managing resources	
Duplicating a colleagues important document and maintaining a copy on outlook which emails reminders before deadlines	Managing resources	First round
I keep spare cables at work so that I can charge my phone/other electronics if they run out/low on battery	Managing resources	First round
I carry deoderant + have another spare at work just in case it is a hot day/forget in the morning. Also applies to water, chewing gum, contact lens solution	Managing resources	First round
I have a spare hoody in my drawer at work because I sit under the air conditioning and it is freezing	Managing resources	
My parents always give a spare set of keys to a neighbour to ensure no one is locked out of the house for too long	Managing resources	
I have set up my oyster card so that it automatically tops up when I am low, as the closest shop to me only accepts cash in the morning, and I am always caught short	Managing resources	

We were in a pub garden and it was much colder than expected. We made use of spare coats which live in the boot of the car. The coats had intentionally been there for that purpose so the 'moment of resilience' was probably months before when they were left there	Managing resources	First round, Workshop
I take photos of my train reservations so that no mistakes are made when handwriting etc. and I can quickly access it when I am at the machine. Also easily accessible if any friends/relatives need the information	Managing resources	
In my drawer at work I have bags of fruit and nut that I buy for snacks at about 11am + 3pm. This keeps me productive before lunch + before dinner	Managing resources	
Lucy, my colleague, cuts up her limes+lemons into segments and freezes them as she never finishes a whole lime when fresh. Also she freezes the dregs of red wine in an ice cube tray to use in stock- this eliminates waste	Managing resources	
Went to a few music concerts- noticed drummers frequently have a 'pot' with several spare drum sticks	Managing resources	Used to assess 10-item scheme
After the staff meeting where it was mentioned that the new Sunday rota had been released I went to the board… and took a photo using my phone and saved it for later use and convenience.	Managing resources	
(ctd. Above) another method is writing down a description of the basic move then for combo movements, just using the general move name	Managing resources	
(ctd. Above) There is a 'call out' log which… is used to help coordinate the worload and as a method of remembering where to go and who needs to be seen… As we work our way down the list the call outs are marked off as being completed	Managing resources	
Preperation the evening prior to travel: getting passports and EHICs together, spare change of clothes for young child, making sure currency available	Managing resources	First round
I needed to get stock from a different unit in pharmacy. I took a picture on my phone of a list my colleague was using to prepare labels from and took with me to remind which items were required	Managing resources	
colleague with post-it note containing todo list and checkboxes on side of monitor	Managing resources	First round
Colleague needed to order some meds for a patient. They put the patients' hospital identifier on their hand (back) to remind them when returning to the pharmacy	Managing resources	
Needed to speak to a Dr about a patients blood tests for levels of a drug over the past year. I took a photo of the results so I would remember them for the conversation	Managing resources	
I always try to carry a small ammount of cash with me incase I need to buy food/drink in a place that doesn't take cards	Managing resources	
I put this diary in my pocket so I remembered to put things in it because its uncomfortable and gets in the way being in my pocket	Managing resources	
Night before went away put family's passports in girlfriends bag so we didn't forget them the next day	Managing resources	
workaround for frail system involves using comand prompt to perform copies- subject saves commands in email for reference	Managing resources	First round
When going to a meeting/interview, I make notes in my phone of all the details I'll need. For example: name/address of people I'm meeting. I'll also take a photo of the location on google maps so I can easily get there without relying on my phones wifi.	Managing resources	
Work/home- I leave windows open on my desktop to ensure I do not forget to read/act on the contents of windows. My PC at home is usually left on hibernate so as to preserve the windows.	Managing resources	Used to assess 10-item scheme
I have a spare oyster card with £10 on it. When I am late but my usual oyster is empty I can use my spare	Managing resources	
I bring cables/chargers to work incase my phone etc runs out of battery	Managing resources	
My mother has a written list of phone numbers because she doesn't trust her phone	Managing resources	First round
When I work for a company which requires wearing a suit, I always keep a spare tie at work. This is incase the one I am wearing gets dirty or I forget to wear one on the way to work (I sometimes don't as it is hot on the tube)	Managing resources	
When I went to Turkey I brought euros with me incase on the way back I got diverted to a european airport	Managing resources	
On holiday I printed off a sheet containing key words that I might need. To help, I also included the pronounciation	Managing resources	First round
At work I have to wear a shirt but no tie. However I always need a tie with me for client meetings. In the morning, I always get dressed including a tie and take the tie off at work so I can guarantee I have brought a matching tie in	Managing resources	
I always aim to have a buffer ammount of money in my bank. This is to cover the cost of buying something unexpected (e.g. getting invited out on the last day of the month when I would otherwise not have any money)	Managing resources	
When I was living abroad my friends at home set up a poker table and put a laptop on one end so, through skype, I could play	Managing resources	
They also, another time, pointed the web cam at the TV so I could watch what they were watching with less of a delay than if I watched it on Canadian TV	Managing resources	
Working on the move -all day. Calendar syncing does not work. To carry out my job effectively I need access to accurate calendar wherever I am (on blackberry and iPhone and MacBook Air). As sync doesn't work -I take a photo once a week of the calendar on my mac, and refer to the photo when I need to look at dates. Also I have started taking a photo on my iphone, as people call me on my blackberry, and I can still look at photo on iphone while taking call on blackberry.	Managing resources	First round, Workshop
I go to work and plan my journeys on tfl journey planner. But because I have got to do 5 or 6 diff journeys I can't store them all (and the website times out) I take screenshots on my iPhone. I then also make note of journey start times in my notes on iPhone so I can quickly refer and make sure I don't miss any appointments. I also do the same with postcodes so I can easily throw them in google maps if I need without dragging emails up. This means if I am on the tube I can still access my journeys without needing connection to internet.	Managing resources	

Went to printers and didn't have memory stick so sent email to myself, opened it on phone to show printer guy what I wanted, then sent him the email with file. This saved me having to fix/find my memory stick! Intentional strategy.	Managing resources	
If a complicated conversation comes up with my boss, and I think I might forget the details I ask if I can record her. I then email this to myself so I can listen back when I have more time/attention span.	Managing resources	
In order to remind myself of emails to deal with, I email them to myself the night before so they are at the top of inbox and easy to find on my mobile, and acts as a reminder.	Managing resources	
Our internet has a fair usage policy (3g Mifi), and it has been stopping me streaming/downloading. We can't have broadband because of our living situation. I bought a second hand android phone and a phone contract which allows tethering and unlimited internet, and we now use this as our main internet supple (by using as a wifi hotspot). This has enabled us to not have a limit on our downloads, without having to take out a contract with BT etc where you are tied in. Intentional strategy.	Managing resources	
Mental lists, repitition when unable to access paper or phone	Other/Misc	Used to develop 10-item scheme
I write a shopping list in area/section so that when I go shopping I do not forget anything and tackle it as quickly as possible	Other/Misc	Used to develop 10-item scheme
Labels placed on boxes of medication, representing that they have been issues they have an audit number, which we can use to trace on our dispensing system. In this case I used this audit number to credit the medication back to stock as it was not required on the prescription. To remind myself to do this I placed the label on my computer screen, whilst depositting the stock back to our <illegible>. Doing this allows me to carry on with my current task as long as I have the audit number on the label I can then at a time convenient for me in my work then return and audit these items back into stock.	Other/Misc	Used to develop 10-item scheme
Repeating words out loud multiple times when learning new vocab in foreign language while on holiday	Other/Misc	Used to develop 10-item scheme
While at work I often stumble across interesting articles. If I don't have time to read them, I'll leave them in a tab and come back to them later during some downtime. This also applies to tasks I have to do that involve web pages. This prevents me wasting time between projects im working on.	Other/Misc	Used to develop 10-item scheme
People write CVs with deliberate ommisisons. This means they can predict questions likely to occur in the interview and can rehearse answers	Other/Misc	Used to develop 10-item scheme
When I moved flat, I took many photos of the new flat incase there were any disputes on the state of the flat when I moved out	Other/Misc	Used to develop 10-item scheme
My elderly grandma's TV remote control has had all but 3 buttons covered up so she does not get confused	Other/Misc	Used to develop 10-item scheme
I have to reel off card details in public quite a bit, so I usually make sure before making a phonecall that may involve paying for something, I have somewhere to go. At <anonymised> it was the private dressing room. Where I work sometimes there is a phone box just outside so I use that. It has to be somewhere where they can hear me, but passers by cant. If I want to sound like I am in an office i put them on hold until I am somewhere quieter	Other/Misc	Used to develop 10-item scheme
Calculated net pay to be paid on <date> against outgoings to give me a remaining estimate for christmas presents to avoid falling short of expectations	Pre check	
Made a hotel reservation and was told to wait until "check-in" to make dinner reservations, given we wouldn't be checking in until 6pm though I called ahead	Pre check	
Had bag packed and ready for work to avoid forgetting anything	Pre check	First round
Did my weekly checks at work- duty manager requires this of staff- other staff doing checks acts as a reminder	Pre check	
Habitual checking of printed hardcopies of forms + organised in order to remind to fill in	Pre check	First round
I go out roaming on the wards in the hospital with a pharmacist, as a team of 2 we are able to go onto wards and assemble medications for discharge/check appropriateness of drugs used on an inpaitent basis	Pre check	
Before taking a journey or route that I'm unfamiliar with, I often simulate the route on google streetview so I visually know what to look out for on the way. This is usually for a journey that involves taking a tube and then walking from the sation. This ensures that I dont take a wrong turn out of the tube station and arrive late	Pre check	First round
Before going to watch a football match I looked up the team lineups because 1. it is very hard to see when at the game and it is often hard to hear the tannoy 2. there is often no signal once in the stadium due to crowds	Pre check	First round
Cutting keys: kept originals separate to avoid 'repeat imitation' causing faulty keys	Precompletion awareness	First round
Filled out my timesheet in the morning before I finished work and left it on my car seat so that I didn't forget to give it to my boss	Precompletion awareness	
Timer for hot water in apartment is broken, so have to turn it on and off manually. Now when we turn it on we also turn on a small LED light to remind us it is on, so that we don't forget to turn it off again (& face expensive electricity bills)	Precompletion awareness	Used to assess 10-item scheme
I put keys straight back into my bag after opening the front door, so that I don't forget them when I next leave the flat	Precompletion awareness	
At work, I get assigned 'footprints'. On receiving, I use outlook's colours to mark the footprint as relevant, not relevant or urgent. I then use the 'flag' system in Excel as follows: flag = to-do, ticked = script written (follow up on next Monday), blank = no action needed. This combination covers all scenarios and makes it easy to see what needs to be done.	preemptive seperation	Used to assess 10-item scheme
When listening to music on spotify I always mark tracks I like with a 'star'. This ensures I can easily keep track of and find recent music I've heard. I also use my starred folder as a huge playlist of tracks which helps me keep track of songs and means i cant add the same song twice	preemptive seperation	

Home- I store photos in folders with names containing dates as YYYY-MM-DD - this means sorting by name orders the folders chronologically	preemptive seperation	First round, Workshop
I have moved into a new flat and have 2 keys which are indistinguishable. I have moved one key next to my keychain so that i can identify which is which.	preemptive seperation	Used to assess 10-item scheme
Driving to work spotted a car in bad condition. Made a decision to "steer clear" the driver proved my decision correct by cutting up another driver	Reinforcement	
Was playing with my neice when I noticed she started to get tired and began swaying slightly (as 2 year olds do) I moved the sharp-cornered furnature to the rooms edge to avoid her hitting her head	Reinforcement	
Wanted to read in the bath but worried about getting ereader wet, so sealed it inside a sandwich bag so it would be protected	Reinforcement	First round
When overtaking cyclists while driving, leave enough space (if possible) tso that even if cyclist fell down the car would not hit them	Reinforcement	First round
Boyfriend had left a large glass of water next to the TV. Moved it to another table in case it got spilled on the TV	Reinforcement	First round
Editing and saving a document on laptop, which I considered to be important. As opposed to just saving the one copy or making one backup, I saved several copies in a few different places. Redundant copies reduced risk of data loss and made it easier to locate in future.	Reinforcement	Used to assess 10-item scheme
Decided to drive to work 5 minutes earlier than usual due to feeling very tired, to ensure I drove carefully	Reinforcement	First round
Lucy, my colleague, is cat sitting and makes a conscious decision to shut the living room door so the cat does not ruin her brand new sofa	Reinforcement	
When carrying heavy shopping for a long journey home, I double bag so that it mititgates the risk of dropping the bag + damaging the contents	Reinforcement	First round
When we go to bed, we leave the key on inside of door. This stops camelot (our property agency) being able to disturb us (they have their own key). But allows us to quickly remove the key and escape ie in case of fire	Reinforcement	
Anticipated having to work late as I had a lot to do so I recorded the football to watch when I got home	Routine adjustment	First round
Arranged a house viewing and labourer (plumber to visit) house at the same time to save on time going back and forth	Routine adjustment	First round
Visited my rental home to show tenants around. Called plumbers ahead of time to arrange a time when they wouldn't be working noisily & messily to make the home more appealing	Routine adjustment	First round
Serving customers at work: whilst serving I noticed a previous customer walk in to make a purchase with me. To ensure I got the sale I asked the customers I was serving to excuse me, I then approached the customers and asked them to wait for me to avoid losing the sale	Routine adjustment	
Took more food to work with me than usual, knowing if I get too hungry I tend to overeat & overspend on takeaways after work	Routine adjustment	First round
Warehouse stock looked to be dissipating rapidly. I called a customer to inform them as I knew they were interested in this particular suite. Avoided customer dissapoointment.	Routine adjustment	
Made my lunch for Sunday knowing I would be going out straight after work today (Saturday) and would not have time to make lunch this evening- kept me from running out of time and having to pay for lunch	Routine adjustment	
Drove to work as normal. Noticed a sign that read: "works on road 4/12" - made a note to avoid that route on that day so I didn't end up being late for work	Routine adjustment	First round
Had to cook Sunday lunch- decided to use slow-cooker whilst at work to avoid any delays cooking after work	Routine adjustment	First round
Playing a game on the xbox, before doing a difficult 'mission' save the game in case I fail and lose progress	Routine adjustment	First round
Boyfriend splashed water on his jeans while washing hands in a restaurant. Used hand driver to try it so that people didn't think he'd had an accident!	Routine adjustment	
Sold some bags of sweets to a lady at work. They had quite a bit of air in the bags so she bit them open and pushed the air out to make them take up less space so she could fit them in her handbag	Routine adjustment	
Placed train ticket in same pocket in bag- habbit, to prevent loss and save time at the ticket machine	Routine adjustment	
Made several mental notes- repeat tings I need to do to myself- wrote these down in notebook in order to tick off at later date	Routine adjustment	
Work- On one of the online forms at work, a text box is very small and hard to read. I type into a larger text box and copy across when finished	Routine adjustment	First round, Workshop
Communicating location on a map from google maps- highlights your position. Send to friend- to make it easier for them to find	Routine adjustment	
An inefficient label ordering system at work results in significant waste. Have suggested batch ordering tickets at work to reduce wastage	Routine adjustment	First round
Consciously replying to emails based on time zone to increase chance of swift response and make effective use of email time	Routine adjustment	First round
On holiday... we used up our heavy toiletries from the hold luggage during the week, so that we would have enough space+weight for souvenirs and would not have to pay extra	Routine adjustment	
Had forgotten phone charger- only realised in the evening just before bed. Phone had low battery so I turned it off to save some battery for the next day. Threat recognised was that I may have no phone battery left the next day and would subsequently not be reachable (added risk as I'd forgotten my wallet!)	Routine adjustment	First round, Workshop
On a night out where I am wearing high heels that I know may hurt me later on, I carry a small pair of pumps that fold up- in my clutch bag and change into these for the journey home	Routine adjustment	First round
During my aerial fitness classes when learning a new move or routine I ask a friend to take a picture on my phone. I do this so at a later date I can refer back to it to remind myself what I need to do	Routine adjustment	

...As with any of my cross-stitches, as I work my way through the pattern I highlight with a coloured ink the parts which are now completed. This allows me to come back to the pattern at my convenience and know where I left off	Routine adjustment	
When learning new things or reading/hearing things I am unsure of at work, I note them down so I remember to look them up later	Routine adjustment	
When at the train station I walk to the part of the platform to board which means I will get on the train at a certain point, which then means I will exit the train on a certain part of the platform. I do this to reduce the distance from the exit of the train station upon arrival therefore reducing the time of my commute	Routine adjustment	
While at work I make a habbit of drinking some water every time I save a document. This ensures I remain hydrated while giving me a reason to stretch my legs	Routine adjustment	
On our software system we created an intermediate screen where the use can select 3 of the most likely options for the next screen to be pre-populated with. The users complained the three options were fixed (we should have provided a none-of-the-above option). They are getting around this by selecting an incorrect option and later modifying the details	Routine adjustment	
A few older customers when asked to provide a screenshot, print the screenshot then scan it into an email. They are not familiar with copy + paste so this is the route they know.	Routine adjustment	
After setting alarm on my phone, asked partner to set up a 'back-up alarm' on his own phone, in case mine didn't work for some reason	Routine adjustment	First round, Workshop
I often do not read texts if I do not have time to respond. Then, when I have time, the text is marked as unread and I do not forget to respond.	Routine adjustment	
We were going for a walk and I am currently 'wearing in' some new boots. Even though it was a hot day, I wore extra thick winter long socks to reduce the friction from the shoes and provide padding. Reduced perceived threat of later discomfort	Routine adjustment	First round, Workshop
I don't drink spirits. This means I start to get full when drinking and this allows me to better judge how drunk I am getting	Routine adjustment	
I make bathroom steamy by turning shower on (I don't have a steamer). It makes plucking eyebrows less painful.	Routine adjustment	First round
I list items on ebay to sell. The main part which makes this a huge hassle is the uploading of photo's to macbook to use in the listing. To avoid this I download the ebay app on iphone. This allows me to take a quick snapshot of what I am selling and then list it straight away with description etc. This avoids the scenario where I have 50 photos, which I then upload individually to my macbook, and by that time I have forgotten the descriptions and have to re look at item. I think this technique speeds my up by about 20%.	Routine adjustment	
My mum cant hear the business phone ring from the kitchen. So she uses baby monitors in study and kitchen so she can hear the phone go and just about make it there in time to answer it.	Routine adjustment	Used to assess 10-item scheme
My scissors broke so I opened tough parcel with a sharp pen..	Routine adjustment	First round, Workshop

Appendix E1: Training and Instructions (Script for Investigator)

STUDY INTRODUCTION & TRAINING

Thanks for your interest. This study is about the resilience strategies (i.e. behavioural adaptations and coping strategies) that people utilise when multitasking and managing interruptions.

Infusion pumps are relatively common devices in healthcare settings, and are used to deliver medication to patients. The main task we are asking you to complete involves entering numbers into two simulated infusion pumps. While you complete this main task, we will also be asking you to complete an additional task, which involves copying numbers from one sheet of paper to another.

During either task, you're very welcome to make use of the materials provided for any purpose, take any actions that you feel will help you complete the task successfully, and you're also welcome to write on any of the paper in front of you. If you have any questions about what you can/cannot do, please ask!

To set up an infusion pump, you need to supply two values: the *rate* of the infusion, and the *VTBI* or *Volume To Be Infused*. In this task, we also have two infusion pumps, so you also need to know which infusion pump to enter information into. The pump nearest to the door is pump number 1, and the other pump is pump number 2.

The *monitor screen* to your right will periodically display a new set of numbers to program into the pumps. When it does, it will look like this- with a white flash and a ringing noise.

When a new set of values appears, the values will only remain on the screen for 25 seconds before the screen will return to black.

The first number displayed indicates which pump to program, either 1 or 2. You then have numbers for rate and VTBI.

To program a pump, first turn it on, using the power button. On the keypad to the right, we have two 'chevron' keys for increasing values (a big up and a little up) and two keys for decreasing values. Use these keys to initially enter the rate. If you press and hold, the rates increase more quickly, and 1200 is the maximum rate. If you accidentally overshoot, you can just use the down keys to adjust.

If you get stuck or wish to start again and clear the values, you can also do this by turning the machine off and then turning it back on again.

When you are happy with the rate, we need to program the VTBI. At the bottom of the screen here, we have three portions- and the three left-most keys above the arrows correspond to them. So to set VTBI, press the middle key. Again, use the arrows to adjust the rate. When done, use this button to select okay, and check the values on this screen. Once you have entered the values, press the green button to begin, and you will be prompted whether you wish to lock (like key lock on an old phone). Set no here, pressing this key.

This screen shows the infusion happening, note you have a timer ticking down to when the infusion completes. Please allow each infusion to complete before you begin entering the next set of values. Once an infusion completes, the screen will change- note the timer has

just been replaced by the volume. Once this screen appears, press the power button to turn the machine off and back on again to quickly clear the current values and begin entering the next set of values.

During the course of the study you will be presented with 12 sets of values to be entered between both pumps, and they may be presented at any time. Please do aim to enter them all if you can.

Because each infusion course takes a while to complete, there will be times when both machines are infusing and you have nothing to do. During this time, we're asking you to complete this simple secondary task.

Here we have two sheets of paper containing numbers, and an empty notepad. We're asking you just to write down all of the numbers that end in '.5' onto the notepad. You can write them in any order, we just wish to have those numbers transferred to this pad.

(Lets just work through one more example on the pump before we get started)

Any questions?

Appendix E2: Investigator Notes Record

#	IFP	RATE	VTBI	TIME	√/X	Point of Interruption	Notes/Strats	PARTICIPANT NUMBER:
1	1	1000	10	0:36		-		
2	2	850	50	3:31				
3	1	850	20	1:24				
4	1	1200	75	3:45				
5	2	750	15	1:11				
6	2	750	5	0:24				
7	2	500	10	1:11				
8	1	500	15	1:47				
9	2	800	40	4:30				
10	1	750	15	1:11				
11	1	1200	60	2:00				
12	2	500	15	1:47				

Appendix E3: Values Contained in Spreadsheet

MACHINE	RATE	VTBI	DURATION
RED	1000	10	0:36
BLUE	850	50	3:31
RED	850	20	1:24
RED	1200	100	5:00
BLUE	750	15	1:11
BLUE	750	5	0:24
BLUE	500	10	1:11
RED	500	15	1:47
BLUE	800	60	4:30
RED	750	15	1:11
RED	1200	60	3:00
BLUE	850	50	3:31
BLUE	1000	20	1:12
RED	850	20	1:24
BLUE	500	15	1:47

Appendix E4: Distractor Task Values

125	240	25.5	600	740	90	25	85	80.5	100
150	35	35.5	50	55	450.5	360	65	90	50
25	60	65	360	10	240	920	75	125	5.5
65	70	95	10.5	420	60	75	200	220	80
800	65	90	15	25	80.5	250	90	15	15.5
80.5	60	45	90.5	600	200	480	930	30	10
360	50	55	10.5	90	250	750	10	80	65
240	940	750	1200	10.5	80	95	350	80.5	5
240.5	840	550	15	80	65.5	25	800	720	100
65	950	1000	35	85	90.5	20	400	25	60.5
45	300	605	300	95.5	10	850	340	345	20.5
85.5	30	75	100	900	75.5	80	25	200	10
90	80	60.5	200	120	430	20	305	90	200

125	60	65	600	90	15	25	80.5	80	100
150	70	95.5	50	45	90.5	600	200	90	50
25	65	90	360	250	90	15	250	125	5.5
65	60	45	10.5	480	930	30	80	220	80
800	80.5	250	15	200	480	930	30	80	15.5
80	200	480	90.5	65.5	90	10	80	65.5	10
360.5	80.5	250	90	75.5	125	350	125	240	65
240	200	480	930	30.5	80	95	350	80.5	5
360	65	90	10	80	65.5	25	800	720	100
920	75	125	350	125	240	25.5	600	740	90
75	200	220	800	150	35	35.5	50	55	45
250	90	15	100	25	60	65	360	10	240
480	930	30	200	120	430.5	20	305	90	200

Appendix F: Strategies Collected from Third Study

STRATEGY	GROUPING/CODE	BROADER THEME
P physically repositions pump 2 at end of training session prior to study start, reorienting it in order to make it easier to view pump 2 screen while sitting nearer pump 1	Moving pumps	Adapting physical task layout
P takes pad (now being used for both primary and secondary tasks) with them round to second pump, repositioning the task	Moving the secondary task sheets	Adapting physical task layout
P repositions secondary task, making it more accessible from pump two (moving to the centre of the desk between the pumps)	Moving the secondary task sheets	Adapting physical task layout
P repositions secondary task, making it more accessible from pump two (moving to the centre of the desk between the pumps)	Moving the secondary task sheets	Adapting physical task layout
P has already repositioned secondary task to be between pumps, upon completing training session	Moving the secondary task sheets	Adapting physical task layout
P relocates secondary task, taking it with them and conducting it partially on the desk next to pump two	Moving the secondary task sheets	Adapting physical task layout
P takes values list over to second pump (and subsequently brings it with them to whichever pump they are working on)	Moving the secondary task sheets	Adapting physical task layout
P Relocates secondary task between the two pumps, moves and carries with throughout the task	Moving the secondary task sheets	Adapting physical task layout
P Relocates secondary task between the two pumps	Moving the secondary task sheets	Adapting physical task layout
Relocating secondary task between the two pumps	Moving the secondary task sheets	Adapting physical task layout
Participant noticed and made use of reflections of laptop screens, using this to monitor the second pump and only attend to it when it had completed its last set of values. This was identified during post-hoc interview and noted.	Use of reflection for concurrently monitoring pumps	Adapting physical task layout
P performs a post-hoc check of values listed as part of secondary task, ticking items to assist in progress tracking during the check	Post-hoc check of secondary task	Checking
P performs a post-hoc check of values listed as part of secondary task, ticking items to assist in progress tracking during the check	Post-hoc check of secondary task	Checking
Post-hoc checking of secondary task, using previously striked-through values as cues to assist by directing attention	Post-hoc check of secondary task	Checking
Post-hoc checking of secondary task, involving striking through each transcribed item and minor annotation with numbers to keep track.	Post-hoc check of secondary task	Checking
Upon completion of primary task and during idle time, begins a post-hoc check of secondary task, ticking values to keep track of progress through checking	Post-hoc check of secondary task	Checking
P has completed secondary task, however during idle time, picks it up and conducts a post-hoc check on it. P uses highlighter pen to assist with progress tracking during check.	Post-hoc check of secondary task	Checking
P performs a post-hoc check of values listed as part of secondary task	Post-hoc check of secondary task	Checking
P performs a post-hoc check of values listed as part of secondary task	Post-hoc check of secondary task	Checking
Begins a post-hoc check of values written as part of secondary task	Post-hoc check of secondary task	Checking
Post-hoc checking that all relevant values have been highlighted	Post-hoc check of secondary task	Checking
Participant makes error while completing post-hoc check of secondary task, restarts check and identifies missing value, subsequently makes correction	Redoing task fully after suspected error	Checking
P Structures list composed during secondary task, using a different side of paper to represent the two pages from the values list, and labelling by row	Organisation or structuring of secondary task list	Organising and optimising information
Participant structures their secondary task list based on pages, separating values from page 1 and page 2	Organisation or structuring of secondary task list	Organising and optimising information
Participant structures their secondary task list based on pages, separating values from page 1 and page 2	Organisation or structuring of secondary task list	Organising and optimising information
Participant structures their secondary task list based on pages, separating values from page 1 and page 2	Organisation or structuring of secondary task list	Organising and optimising information
P organises list by including circled numbers denoting the collumn for each value	Organisation or structuring of secondary task list	Organising and optimising information
Participant became unsure of how to operate pump, requiring intervention by experimenter. Upon being again trained to enter values into the pumps, P makes instructions note on Post-It to help remember the steps required to operate the pumps	Writing additional supplementary instructions	Organising and optimising information
P adds annotation in the form of instructions to secondary task list: "0.5 all numbers ending in 0.5"	Writing additional supplementary instructions	Organising and optimising information

P underlines and/or strikes through items on secondary task (printed list of values) to assist progress tracking upon task resumption	Marking the secondary task sheet	Progress tracking
P underlines and strikes through items on secondary task (printed list of values) to assist progress tracking upon task resumption	Marking the secondary task sheet	Progress tracking
During secondary task, P strikes through values to assist progress tracking	Marking the secondary task sheet	Progress tracking
Participant makes very minor annotation to secondary task values sheet: 1 x dash and 1 x circling of value, to assist with progress tracking and mark items upon intteruption	Marking the secondary task sheet	Progress tracking
P Numbers each column on secondary task sheet to facilitate placekeeping during check and help organize their values	Marking the secondary task sheet	Progress tracking
P strikes through items on secondary task (printed list of values) to assist progress tracking upon task resumption	Marking the secondary task sheet	Progress tracking
P strikes through items on secondary task (printed list of values) to assist progress tracking upon task resumption, using vertical lines through all values.	Marking the secondary task sheet	Progress tracking
P strikes through items on secondary task (printed list of values) to assist progress tracking upon task resumption	Marking the secondary task sheet	Progress tracking
Strikes through each value on secondary task value sheet to assist placekeeping	Marking the secondary task sheet	Progress tracking
Marks place in secondary task by writing a small tick style notation on printed values sheet	Marking the secondary task sheet	Progress tracking
P uses finger placement as cue to track progress in secondary task, leaving finger on values list while looking up and attending to monitor screen.	Using finger as placeholder	Progress tracking
P uses finger as cue for placekeeping during secondary task	Using finger as placeholder	Progress tracking
Using finger as cue to assist progress tracking in secondary task	Using finger as placeholder	Progress tracking
P places new list carefully on top of secondary task to occlude all but the first collumn, helping progress tracking with secondary task	Using paper to occlude completed values	Progress tracking
Careful and intentional placement of pen as cue on secondary task sheet to assist with placekeeping upon task resumption	Using pen as placeholder	Progress tracking
P uses plastic tab to assist progress tracking in secondary task. Rather than moving and replacing on each item, P works through grid in rows, and uses the tab as a cue indicating which row they are working on [11:06]	Using plastic tab as placeholder	Progress tracking
Participant takes a blue plastic tab and uses it to track progress of secondary task in place of finger when required to move to a pump.	Using plastic tab as placeholder	Progress tracking
P switches from using Post-It notes to writing down values into a list on same pad as performing secondary task. P folds list to organize it [network 14:14] and rips off portion of page which contained values for primary task [network 15:37]	Recording as a structured list	Recording or Retaining Values
P immediately writes down values onto piece of paper upon being presented on monitor screen (including pump number). Crosses out values once they have been entered	Recording as a structured list	Recording or Retaining Values
Recording new values from monitor screen onto external list using pad of paper. Values are striked through upon completion	Recording as a structured list	Recording or Retaining Values
P records some values on a Post-It note as new values are presented while list is out of reach. P attaches Post-It note to pump 1, serving as a queue for relevant pump [network 13:42] and discards Post-It once values entered into pump, scrunches it and places it aside [network 16:33]	Recording onto Post-It notes	Recording or Retaining Values
P records each value from monitor screen onto Post-It notes, carries them while on foot and uses smaller form factor to be able to take notes while up and moving. P discards post it once values entered into pump, scrunches it and places it aside [GoPro 00:55, network 00:46] P discarded Post-It notes in two distinct piles, based on pump [network 03:30]	Recording onto Post-It notes	Recording or Retaining Values
P uses Post-It notes to record some values in a mobile manner (while walking between pumps). P attaches Post-It notes to pumps [Network 03:20]. P then strikes through and discards post it once values entered into pump, scrunches and places aside (P puts discarded Post-It notes into a single pile) [Network 05:18].	Recording onto Post-It notes	Recording or Retaining Values
P records some values onto Post-It notes, only when multitasking. Later picks up pad and moves to other pump – mobile. P transfers values from one (small) Post-It note onto a larger Post-It note, discarding previous notes [Network 06:54]. P places Post-It note onto pump (note later falls off) [Network 13:35].	Recording onto Post-It notes	Recording or Retaining Values
P makes use of Post-It notes (mobile). P takes note of every single value from monitor screen on a separate Post-It note, including number sequence (in circle). Discarding of Post-It notes once values entered, notes placed into a single pile [Network 01:11].	Recording onto Post-It notes	Recording or Retaining Values
P uses Post-It notes to record values. Unlike P2, this is not done for every value, just some, where values have started to 'stack up' - i.e. initial values entered straight into pumps, but when new values arrive while pump interaction in progress, P begins to record them. P then discards Post-It note once values have been entered [network 02:33]. P now attaches post-it note to pump 1, serving as a queue for relevant pump [network 02:46]. Post-It note falls off pump, P takes off remaining notes and places them in a 'queue' on the desk [GoPro 06:12, network 06:08]	Recording onto Post-it notes	Recording or Retaining Values
P records some values on Post-It notes (initial values entered straight into pumps, begins to record when forced to multitask). P attaches Post-It note note onto pump [network 01:34]. P then uses Post-It notes as a mobile resource, walking around with pad [network 01:37]. Upon completion, Post-It notes are discarded into a pile [GoPro 01:55].	Recording onto Post-it notes	Recording or Retaining Values
Use of Post-It notes, only 7 sets of values recorded. P walks around with Post-it notes, mobile. P uses a different note for pump 1 and pump 2. Values are crossed out upon entry.	Recording onto Post-It notes	Recording or Retaining Values
Use of Post-It note (mobile). P takes note of every single value on a separate Post-It note, titles each Post-It note with pump number	Recording onto Post-It notes	Recording or Retaining Values
Use of Post-It note cues (mobile but only occasional- 6 sets of values). Uses ticks partially (on 3) to indicate when completed	Recording onto Post-It notes	Recording or Retaining Values

P notes down every value onto Post-It note as soon as it appears. In first case, Post-Its remain on desk however from second case onwards, P takes Post-It pad and writes values while moving between pumps - mobile. P then ticks values upon completion.	Recording onto Post-It notes	Recording or Retaining Values
Participant records values from monitor screen onto Post-It note (mobile, 7 sets of values). Participant labels pump number in 2 cases, and strikes through entered values in 3 cases.	Recording onto Post-It notes	Recording or Retaining Values
Participant records every set of values from monitor screen onto a single Post-It note, includes pump number, ticks to indicate done for initial 3 values then switches to striking through completed items. Post-Its are mobile, P takes them from pump to pump	Recording onto Post-It notes	Recording or Retaining Values
Using Post-It notes to record all values from monitor screen. Handheld and mobile, crosses values out upon being entered (partial, 9 sets of values)	Recording onto Post-It notes	Recording or Retaining Values
P records some values onto Post-It notes, only when multitasking. Later picks up pad and moves to other pump – mobile.	Recording onto Post-It notes	Recording or Retaining Values
Use of Post-It notes, only 5 sets of values recorded. P walks around with Post-it notes, mobile.	Recording onto Post-It notes	Recording or Retaining Values
Upon arrival of new values, P verbally rehearsing values under breath to assist in retaining them while entering previous set of values into pump	Verbally rehearsing values to assist retention	Recording or Retaining Values
Upon arrival of new values, P verbally rehearsing values under breath to assist in retaining them while entering previous set of values into pump	Verbally rehearsing values to assist retention	Recording or Retaining Values
Upon arrival of new values, P verbally rehearsing values under breath to assist in retaining them while entering previous set of values into pump	Verbally rehearsing values to assist retention	Recording or Retaining Values
Upon arrival of new values, P verbally rehearsing values under breath to assist in retaining them while entering previous set of values into pump	Verbally rehearsing values to assist retention	Recording or Retaining Values
Upon arrival of new values, P verbally rehearsing values under breath to assist in retaining them while entering previous set of values into pump	Verbally rehearsing values to assist retention	Recording or Retaining Values
Upon arrival of new values, P verbally rehearsing values under breath to assist in retaining them while entering previous set of values into pump	Verbally rehearsing values to assist retention	Recording or Retaining Values
Participant verbally rehearsing latest set of values from monitor screen while attending to previous set	Verbally rehearsing values to assist retention	Recording or Retaining Values
Verbal rehearsal (inaudible) while entering values into pump 2	Verbally rehearsing values to assist retention	Recording or Retaining Values
Verbal rehearsal (rehearsing pump values) while entering values into pump 2	Verbally rehearsing values to assist retention	Recording or Retaining Values
Verbal rehearsal (inaudible) while entering values into pump 1	Verbally rehearsing values to assist retention	Recording or Retaining Values
Verbal rehearsal (rehearsing pump values) while entering values into pump 1	Verbally rehearsing values to assist retention	Recording or Retaining Values
P tears off blank sheet of paper from pad to compose a structured list, list contains a column for each pump (List contains numbers from item 3, and is later striked through to assist progress tracking). Upon entering values, P strikes them off list	Recording as a structured list	Recording or Retaining Values
P is entering values into a pump as new values arrive on monitor screen. P momentarily defers attending to monitor to finish pump programming	Deferral of interruptions	Restructuring task sequence
P is entering values into a pump as new values arrive on monitor screen. P momentarily defers attending to monitor to finish pump programming	Deferral of interruptions	Restructuring task sequence
P defers entering values on pump one when new values for pump 2 are presented. P completes entry of values onto pump one, deferring attending to new values for approximately 18 seconds.	Deferral of interruptions	Restructuring task sequence
P momentarily defers attending to new values on monitor screen while already entering values into a pump.	Deferral of interruptions	Restructuring task sequence
P momentarily defers attending to new values on monitor screen while already entering values into a pump.	Deferral of interruptions	Restructuring task sequence
P momentarily defers attending to new values on monitor screen while already entering values into a pump.	Deferral of interruptions	Restructuring task sequence
Deferral, completing number entry on pump prior to attending to new values	Deferral of interruptions	Restructuring task sequence
P momentarily defers interruption of new values arriving on monitor screen while completing the secondary task	Deferral of interruptions	Restructuring task sequence
Split second deferral (1-2 secs) to finish entering a set of values into pump two, prior to attending to new values on monitor screen	Deferral of interruptions	Restructuring task sequence
P is entering values into a pump as new values arrive on monitor screen. P momentarily defers attending to monitor (1-2 seconds) to finish pump programming	Deferral of interruptions	Restructuring task sequence
P is engaged in secondary task, however upon new values being presented on monitor screen, temporarily defers to complete the entry they are attending to as part of secondary task (deferral duration only 1-2 seconds)	Deferral of interruptions	Restructuring task sequence
P is engaged in secondary task, however upon new values being presented on monitor screen, temporarily defers to complete the entry they are attending to as part of secondary task	Deferral of interruptions	Restructuring task sequence
Participant programming pump 1 when new set of values arrives. P defers attending to new values for approx. 10 seconds in order to complete entering pump 1 values	Deferral of interruptions	Restructuring task sequence
Participant momentarily (1 second) defers new values being presented in order to complete writing as part of secondary task	Deferral of interruptions	Restructuring task sequence
Deferral for 5 seconds, as new values arrive on monitor screen, P completes programming on pump 2 which is already in progress	Deferral of interruptions	Restructuring task sequence
Deferral (momentary, 1-2 seconds) to continue button presses on pump 2 as entry is in progress, before attending to new values presented on monitor screen	Deferral of interruptions	Restructuring task sequence
Reorganising task structure for secondary task. Uses highlighter pen to highlight all relevant values prior to later recording them on participant list	Reordering sequence of secondary tasl	Restructuring task sequence

Appendix G: Publications List

Day, J. (2013). Exploring how individuals deploy resilient strategies. Poster presented at World Usability Day, 'Healthcare: Collaborating for Better Systems', London, November 2013.

Day, J. (2013). Exploring resilient strategies arising from interrupted interactions. Talk presented at CHI+MED Doctoral Consortium, UCL, June.

Day, J., & Buchanan, G. (2013). Investigating resilience strategy creation and use in the context of interrupted action. Paper presented at Doctoral Consortium at 14th IFIP TC13 Conference on Human-Computer Interaction (INTERACT 2013), Cape Town, September.

Day, J., & Buchanan, G. (2014). Revising a categorisation scheme for resilience strategies using app-captured self-report data. Poster presented at the ISKO UK meeting on "Knowledge Organization goes Mobile", London, November 2014. (Best poster prize.)

Buchanan, G., & Day, J. (2014). On individuals' resilience strategies: Drawing and applying theories. Paper presented at the Workshop on "HCI Research in Healthcare: Evidence to Practice" at CHI 2014, Toronto, Canada, April 2014.

Day, J., & Buchanan, G. (2015). Lessons from patients: Resilience strategies and behaviours. Paper presented at the Workshop on "Crossing HCI and Health: Advancing Health and Wellness Technology Research in Home and Community Settings" at CHI 2015, Seoul, South Korea, April 2015.

Day, J., Furniss, D., & Buchanan, G. (2015). Meals and Ingredients: Coping with Compound Resilience Strategies. Proceedings of the 6th Symposium of the Resilience Engineering Association, Lisbon, Portugal, June 2015.

Day, J. (2015). Understanding Individuals' Everyday Strategies for Resilience. Presented at the Young Talents (Doctoral Consortium) feature at the 6th Symposium of the Resilience Engineering Association, Lisbon, Portugal, June 2015.

Day, J., Buchanan, G., & Makri, S. (2015). Introducing the RSDiary App for the Collection of Resilience Strategies. Poster presented at the European Conference on Cognitive Ergonomics (ECCE 2015), Warsaw, Poland, July 2015.

Day, J., Buchanan, G., & Makri, S. (2015). Learning Lessons from Controlled Studies to Elicit and Investigate Users' Resilience Strategies. Poster presented at the 15th IFIP TC13 Conference on Human-Computer Interaction (INTERACT 2015), Bamburg, Germany, September 2015.

Day, J., Buchanan, G., & Makri, S. (2015). When Things Go Right: Learning from Resilience Strategies. Poster presented at the CHI+MED Symposium on Patient Safety with Interactive Medical Devices, Reading, UK, June 2015.

Day, J., Buchanan, G., & Makri, S. (2015). Reflecting on Users' Strategies for Resilient Interactions. IFIP WG 13.5 Workshop on Resilience, Reliability, Safety and Human Error in System Development. Adjuct proceedings of the 15th IFIP TC13 Conference on Human-Computer Interaction (INTERACT 2015), Bamburg, Germany, September 2015.