Mental Representations and processes in Intertemporal Choice

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ABSTRACT

In intertemporal choice the subjective value of a reward decreases as the delay until its receipt increases, a phenomenon known as delay discounting. Discounting rates vary substantially across individuals, and demographic correlates only explain a small proportion of the variability. This thesis explores potential reasons for differences in discounting across individuals by looking at whether they may be more driven by differences in the underlying representation of the options under consideration or processes by which decisions are made.

The first strand explored the relationship between delay discounting and two key phenomena linked to the way the future is represented in mind: Temporal construal, where delay qualitatively affects the way an event is represented, and episodic future thinking (EFT; the ability to project oneself through time to pre-experience a future outcome). Although variability across individuals in all three measures – discounting, construal and EFT – was substantial, associations among the three constructs were weak, suggesting differences in discounting are not mediated by differences in the other variables.

The second strand used eye tracking to investigate processes underlying discounting, by examining the frequency of transitions between different attributes in discounting choice options. Participants made a fairly even combination of within-attribute and within-option transitions, suggesting a mixed strategy for evaluating options. More within-attribute transitions generally predicted less discounting.

The strands also examined potential mechanisms for two manipulations known to affect discounting: The delay-date effect, where describing future rewards using dates rather than delays reduces discounting; and episodic tagging, where adding a participant-specific episodic cue to future outcomes similarly reduces discounting. Despite behavioural similarities, eye movements patterns differed, with more within-attribute transitions for dates than tags.

Overall, the findings help rule out some plausible representational and process-driven accounts for individual differences in delay discounting and provide insights into some of the general features that underlie intertemporal choice.

1 OVERVIEW

Time is a central concept in psychology that is of particular relevance to judgement and decision making as people make *intertemporal choices* (Loewenstein & Thaler, 1989). Although intertemporal choice encompasses the many ways in which an individual's decisions in the present has an impact on their future, it is often used in reference to dilemmas between costs and benefits that will occur at different points in time in the future.

Examples of such intertemporal choices can be choosing between an unhealthy snack now or sticking to a healthy diet for a healthier life in the long run, or choosing between saving for one's pension instead of spending excessively in the present. These are both examples of delaying gratification, where people defer something pleasant in the present in order to get something even more rewarding in the future. Intertemporal choice can also involve losses, such as getting a vaccine now, which is unpleasant, or instead getting measles later, which is certainly more unpleasant. These types of choices are important because of their implications in pension saving, healthy lifestyles, and generally impulsive behaviours that have self-defeating outcomes in the long run.

Delay discounting, or *temporal discounting*, is a way of quantifying the decline in subjective value with increasing delay (see Frederick, Loewenstein & O'Donoghue, 2002). People generally want to receive rewards sooner rather than later, and for those rewards to be greater rather than smaller. But sometimes one option is better along the reward dimension but not as good on the temporal dimension, whereas the other option is superior along the temporal dimension and inferior along the reward dimension. Equally, people often want to make payments later rather than sooner, and for them to be smaller rather than larger. But one might have to choose between a smaller payment sooner or a larger payment later, such as when paying off loans and debts. It is therefore said that people *discount* the future, because their valuation of a good decreases with increasing delay.

Although intertemporal choice in the research literature often refers to the aforementioned cost and benefit dilemmas, there are other areas of decision making involving time that do not deal with how delay affects valuation. For instance, *affective forecasting* is the study of how well people can predict and anticipate their emotional states in the future (Wilson & Gilbert, 2003), and the *planning fallacy* shows how people underestimate how long it will take them to complete a task (Buehler, Griffin & Ross, 1994). More relevant to this thesis, another area of intertemporal choice is that of temporal construal (Liberman & Trope, 2008; Trope & Liberman, 2010) in which mental representations of future events change over time. More specifically, the near and distant future are represented categorically differently, and these different mental representations can in turn influence their intertemporal choices. Delay discounting will be the primary focus of this thesis, though construal level theory will make an appearance in Chapter 3 when exploring the role of mental representations in intertemporal choice.

A conventional discounting task in an experimental delay discounting study, will usually consist of a choice between a smaller-sooner and a larger-later option, where one option is a relatively smaller hypothetical amount of money delivered sooner, and the other option is a relatively larger amount of money delivered later (Kirby, Petry & Bickel, 1999; Frederick, Loewenstein & O'Donoghue, 2002). Decision makers may be asked to choose between £50 in 2 days or £100 in a week. There are other versions of delay discounting tasks, such as matching tasks (e.g., "how much money would you need to wait a week instead of receiving £50 in 2 days?") or where the outcome is a negative one (e.g., "pay £50 in 2 days or pay £100 in a week"), but it is the conventional smaller-sooner vs. larger-later task that will be a recurring measure of delay discounting in this thesis. These tasks consist of two options that each have two attributes (delay and amount), and the way in which these are mentally processed will be explored in Chapter 4.

1.1 THESIS MOTIVATION

The study of intertemporal choice and delay discounting specifically is an area of judgement and decision making (JDM) psychology that has its origins in traditional economics. Classical economic models of intertemporal choice have largely been concerned with developing optimal choice models that with great simplicity can quantify how much decision makers should value outcomes as a function of how far into the future they will be received (Fisher, 1930; Samuelson, 1937). Although the JDM area of psychology has been more concerned with giving a psychological account that best describes how people actually make intertemporal decisions, the predominate focus is still about modelling choice behaviour. With this thesis I wish to focus on describing intertemporal choice in psychological terms by exploring the mental representations and processes involved. In this thesis I will use mental representations to describe how the mind symbolises the external world, and mental processes to describe what the mind does with these mental representations as it comes to a decision.

There is widely documented variability in individual's discount rates, and most of this variation is largely unaccounted for, even when taking demographic and socioeconomic factors into account (Carter, Meyer & Huettel, 2010; Figner et al., 2010; Loewenstein, Rick & Cohen, 2008). Empirical evidence from both the JDM area as well as memory research suggest that the way in which people mentally represent their own personal future influences their discounting behaviour. From construal level theory (Liberman & Trope, 2008; Trope & Liberman, 2010), specifically temporal construal, the way in which people think about the future in more concrete or more abstract manners can reduce or increase discounting (Malkoc & Zauberman, 2006; Malkoc, Zauberman & Bettman, 2010; Kim, Schnall & White, 2013). Similarly, in memory research on episodic future thinking (Peters & Büchel, 2010; Benoit, Gilbert & Burgess, 2011; Cheng, Shein & Chiou, 2012; Liu et al., 2013; Lin & Epstein, 2014), ,reminding people of what they are going to do at the time of receipt in a conventional delay discounting task reduces their discounting (Peters & Büchel, 2010).

Additionally, the way options are presented can influence decision-makers' preferences and in turn lead to various effects (see 'The Construction of Preference' by Slovic, 1995), such as the date-delay effect (Read et al., 2005). Such instability of preference suggest that the options might be mentally represented differently, based on choice context. The date-delay effect is when people discount less when delays are presented as calendar dates (e.g., "3 January 2021") than numerical waiting time (e.g., "3 weeks"). Thus, it could be that some of the variability in individual differences in discounting can be accounted for by individual differences in construal levels or in the extent to which someone thinks episodically about their personal future. And given the similar effect of construal level, episodic future thinking and calendar dates on reducing discounting, the relative contributions of each factor will be examined in the first strand of research in this thesis. The term individual differences is used throughout this thesis to refer to variability or differences across individuals in the measures – discounting, construal, future thinking – used in the these to capture an aspect of the way in which individuals represent the future, and not personality dispositions or demographic variables as such.

The second strand of research in this thesis concerns what mental processes and comparison strategies underlie delay discounting preferences. Most research on discounting is focused on choice rather than on the underlying processes that lead to those preferences, of course different decision processes can lead to different preferences, and as such, it might be informative to examine the decision process as a whole to try to account for some of the variability in discounting. In order to do so, eye movements were recorded with an eye tracker while decision-makers chose between smaller-sooner and larger-later options. The aims were twofold: to describe what sort of fixations and transitions between fixations people make in a conventional binary delay discounting choice task, and to put option-based and attribute-based discounting models to the test. Simply put, traditional discounting models consider options in isolation, weighing amounts by delays, predicting that people would look more between that option's attributes. More recent attribute-based models compare options directly across each attribute dimension, predicting that people would look more across options, within each attribute.

To summarise, most research on delay discounting has largely focused on the values of the attributes and the conditions in which they differ. There has been less research on delay discounting from a cognitive psychological perspective, specifically focused on the representations and processes involved. As discussed above, there is ample evidence that the way in which options and attributes are presented influence delay discounting, which might be due to differences in mental representation. There is also a large discussion about what processes people are employing when choosing between smaller-sooner and larger-later options, whether they compare options or attributes directly. Thus, the aim of this thesis is to take a cognitive psychological approach, to examine what people are thinking about (representations) and what they are doing (processes) to understand why there are such vast individual differences in discounting behaviour. In order to investigate whether differences in representations and processes can explain individual variability in discounting, this thesis has two strands of research. The first strand of research will explore what mental representations people have of the near and distant future, and how these mental representations influence intertemporal choice. The second strand of research will examine what mental processes people go through during intertemporal choice, whether they compare options or attributes directly.

1.2 MAIN FINDINGS

As outlined in the thesis motivation, the research of this thesis is split into two strands, the first of which focuses on how mental representations affect discounting, and the second focusing on how processes affect discounting with the use of eye tracking methodology. Together, the two strands look at the extent to which individual variability in mental representations and processes may account for some of the individual differences in discounting.

The aim of the three studies in the first strand of research was to explore whether some of the variability in individual's discount rates could be accounted for by individual differences in episodic future thinking (EFT) or temporal construal. Episodic future thinking is the capacity to mentally pre-experience personal future events (Atance & O'Neill, 2001; Schacter, Addis & Buckner, 2008; Szpunar, 2010). Perhaps people who discount more are also people who have less representation richness in their EFTs and who make more low-level construals overall. However, across all studies, there was no relationship between discounting and either EFT or temporal construal. Therefore, although EFT and temporal construal can influence intertemporal choice, individual differences in these constructs do not appear to be the driving discount rates.

Aside from the main aim, there were three key findings of the first strand of research. First, the episodic-tagging effect, when verbal reminders of personal future plans reduce discounting, and the date/delay effect, when delays written as calendar dates reduce discounting, appear to be related effects. When delays were accompanied by episodic tags to prompt EFT, they reduced discounting, but there was no further attenuation of discounting when the delays were written as calendar dates. This interaction effect suggest they might be driven by the same underlying mental representation of the decision maker's personal future. Second, individuals who made more high-level construals also had greater representation richness in EFT. Third, the simplified version of the episodic-tagging paradigm of Peters and Büchel (2010) proved a robust and efficient procedure for online studies.

The aim of the two studies in the second strand of research was to explore whether people make more within-option comparisons relative to within-attribute comparisons, by measuring whether they made more fixation transitions within options or along attributes. This is, to my knowledge, the first attempt at using eye tracking technology to examine the relative frequency of within option transitions (as predicted by option-based models) and within attribute transitions (as predicted by attribute-based models). The results indicate that people make a combination of both comparison strategies, as there was a near even split between the two types of transitions.

There were some other interesting results of the eye tracking studies as well, as episodic tagging and date-formats were incorporated into the studies. In one study options were presented as either delays or dates, and in the other study one, both or neither option were accompanied by episodic tags. First, there were more fixation transitions made within attributes for the date-format relative to the delay format, but episodic tagging led to relatively more within-option type transitions. On the onehand the research literature, as well as this thesis, show a similar attenuating effect of episodic tags and date format on discounting. Moreover, the first strand of studies in this thesis showed an interaction effect between the two, where there were no additive effects of having both dates and episodic tags within a single trial. On the other hand, the second strand of research measuring eye movements show the comparison strategies used for conditions of episodic tags and date format appear categorically different. These different comparison strategies uncovered by the eye tracking measures could not have been detected with behavioural data alone.

Second, the episodic tagging effect of Peters & Büchel (2010) was replicated when both options were episodically tagged. In the original study, only the larger-later option was tagged, which leaves the possibility that the attenuated discounting was due to an attentional shift to the larger-later option, rather than engaging in EFT. However, as discounting was still attenuated when both options were tagged, this suggests that the episodic tagging effect is not merely an attentional one. There was also greater discounting when only the smaller-sooner option was tagged, suggesting either some role of attention, or that the smaller-sooner option can benefit from being mentally represented in an even more episodic manner than it is at default.

Third, across both studies, people look more at the attributes they like more: shorter delays and greater amounts, and that the option they looked at more predicted that they would choose that option. In the majority of the conditions, more within-attribute transitions predicted less discounting. Although date format and episodic tagging had the same effect on discounting, more within-attribute transitions were made in the date-format and more within-option transitions were made when both options were episodically tagged. Even though both conditions led to less discounting, the extent to which they made within-option or within-attribute transitions did not predict whether people discounted more or less. Thus eye-tracking data revealed differences in the processes involved in these two similar effects.

1.3 CONCLUSION

In this thesis I have brought together two ideas from the intertemporal choice literature to explore how people mentally represent the future and some of the processes involved. First, there is the idea that preference is constructed (Slovic, 1995) and this has been demonstrated in various areas of the JDM literature, including delay discounting. People discount less when reminded of their future plans (e.g., Peters & Büchel, 2010), when delays are written as calendar dates (Read et al., 2005) and when temporal construal is manipulated (e.g., Malkoc et al., 2006, 2010). All these effects suggest that how people mentally represent the future influences whether they discount more or less. Although it is worth noting that these context effects in discounting leave room for some underlying consistent preferences, but that these are affected to some degree by irrelevant contextual factors. Second, there is a continuum of discounting models, ranging from attribute-based to option-based, and these make different predictions for how people mentally represent the options and their attributes. By exploring these mental representations, I have sought to account for some of the individual variability in discount rates.

To summarise, the key findings of this thesis are as follows:

- Individual differences in delay discounting were not related to individual differences in temporal construal or episodic future thinking.
- Episodic future thinking and temporal construal appear to be related, as individuals with greater episodic future thinking representation richness had more high-level construals.
- There was an interaction effect between episodic tagging and the date/delay effect, where there was no further attenuation of discounting when both calendar dates and episodic tags were employed, suggesting that the two are based on a shared underlying mechanism.
- People appear to use a combination of option-based and attribute-based comparisons in conventional delay discounting tasks.

- Replicating the standard findings in temporal construal proved difficult and sensitive to whether it was online or in the laboratory, suggesting the effect might not be that powerful.
- Looking more at the smaller-sooner delay predicted more smaller-sooner choices and looking more at the large-later amount predicted more larger-later choices, in line with the gaze-cascade effect.
- People made more within-attribute comparisons when delays were written as calendar dates, but more within-option comparisons when delays were accompanied by episodic tags. Thus, it appears these effects, though they might share the same underlying mechanism, lead to different comparison strategies.
- Generally, more within-attribute transitions predicted less discounting. The only exceptions were when both options had episodic tags or when delays were written as calendar dates.

One of the unique contributions of this thesis is that it is the first to directly test the predictions of option-based and attribute-based classes of models of delay discounting in terms of process tracing with an eye tracker. It is also the first to simultaneously explore the episodic-tagging and date/delay effect to see if they share underlying representations, and the first to explore episodic future thinking and temporal construal directly. Finally, this work further supported the episodic-tagging effect by ruling out the possibility that it is merely an attentional effect and did so with a simplified version of the Peters and Büchel (2010) procedure that can successfully be carried out in online studies.

This thesis begins to give some insights into what people think about and what they do mentally when discounting the future, which may reflect similar changes to underlying mental representations. There was evidence to suggest that individual differences in temporal construal and episodic future thinking are related. Also, episodic tagging and the date/delay effect may share some underlying mental representations but appear to differ in how they are processed. The findings of this thesis highlight the importance of not just considering the values in delay discounting choices, but also cognitive factors that pertains to what is going on in decision-makers' minds in terms of how information is represented and processed.

2 LITERATURE REVIEW: DELAY DISCOUNTING

Delay discounting falls under the broader study of *intertemporal choice*, which is when decisions made in the present affect outcomes at future points in time. People make trade-offs between benefits and disadvantages of outcomes which are realised at separate points in time by deciding *what*, *how much* and *when* to do something. For instance, an individual might choose between a cigarette now or better health later, or between travelling the world or saving for their pension. Any decision of great consequence will have an impact on the future and thus be an intertemporal choice, and this has therefore become a central field of study for both psychologists and economists.

Delay discounting is about *how* delay affects value, more specifically the way in which an outcome's subjective value decreases as the delay until its receipt increases. Most people prefer greater rewards over smaller ones, and to have them sooner rather than later. But sometimes one option is smaller but sooner, and the other option is larger but later. People are *discounting* when they forego a better but later outcome for a sooner but otherwise inferior outcome, and this behaviour has consequences for numerous societal issues, such as substance abuse, gambling and obesity. While papers on delay discounting have been published at an increasing rate in recent years (Frederick & Loewenstein, 2002; Madden & Bickel, 2010; Odum; 2011; Frost & McNaughton, 2017; Rung & Madden, 2018), the area of study has been around since at least the 18th century.

The next section gives a general introduction to the field of intertemporal choice research, starting with the early economical models of the 19th century, to increasingly psychological models from recent decades. The following sections describe these models as well as research demonstrating how time preference is both an individual difference but also subject to numerous contextual effects. This literature informs to both strands of research in this thesis, focusing on the role of mental representations and processes in intertemporal choices and how individual differences and contextual effects affect these.

2.1 HISTORY

The nineteenth century economist John Rae (1834, as cited in Frederick & Loewenstein, 2002), following in the footsteps of Adam Smith, aspired to understand why countries differed in prosperity. Smith claimed that wealth was determined by how much labour was allocated to build up capital. However, Rae argued that this failed to explain to *how* labour was allocated. He therefore introduced a psychological factor, *the effective desire for accumulation*, which varied from country to country and determined to what extent these countries invested in capital. As such, people's assumed future-oriented preferences for accumulation represent the first psychological theory of intertemporal choice.

Rae added another 4 psychological factors that either inhibited or promoted the effective desire for accumulation. The motivation to contribute to one's society and the inclination to exhibit self-restraint promoted accumulation, whereas the uncertainty of human life and desire for instant gratification inhibited accumulation. These factors later branched out into two different views: The abstinence perspective and the anticipatory utility view.

The abstinence perspective states that people prefer present and future outcomes equally, but the degree to which they experience discomfort from deferring gratification determines how much importance present outcomes are given (Senior, 1836, as cited in Frederick & Loewenstein, 2002). That is, time preference variability in the general population depends on the extent individuals feel discomfort from denying themselves instant gratification. Contrary to this, the anticipatory utility view holds that people prefer present outcomes over future outcomes, but the degree to which they anticipate future outcomes determines whether they defer gratification (W. Jevons, 1888, as cited in Frederick & Loewenstein, 2002; H. Jevons 1905, as cited in Frederick & Loewenstein, 2002). In other words, individuals' inclination to mentally represent the future can explain variability in time preference. Despite their differences, these two views both agree that intertemporal choice relies on immediate feelings, whether it is the discomfort of deferring gratification or the satisfaction of anticipation.

Böhm-Bawerk (1889, as cited in Frederick & Loewenstein, 2002) developed a theory of intertemporal choice which argued that people systematically underestimate future wants. Like his predecessors, Böhm-Bawerk also took a heavily psychological perspective, but his approach marked a transition towards talking about intertemporal choice in terms of resource allocation over different points in time. People were now described as making *trade-offs* between time and resources.

Finally, Fisher (1930) formalised Böhm-Bawerk's approach by plotting intertemporal choice using indifference curves between allocation of resources to current year and next year consumption, with present-year consumption on the horizontal axis and next-year consumption on the vertical axis. This illustration of trade-offs showed how someone's time preference and diminishing marginal utility determines their marginal rate of substitution. In other words, an intertemporal choice is the joint outcome of *when* someone wants to receive a good and *how* desirable that outcome is to them. Fisher also discussed psychological factors, such as the four Rae factors and the ability to envision the future, the flip side to Böhm-Bawerk's notion of underestimation of future wants.

These initial models are important because they all emphasise the importance of psychological factors in intertemporal choice. The *discounted utility model* (Samuelson, 1937), that would later become the benchmark model for temporal discounting, discarded these psychological motives, reducing intertemporal choice to a simple discount rate. The following 3 sections (1) describe this model, (2) presents an emerging field of psychology that challenged its ability to describe intertemporal choice behaviour in favour of (3) hyperbolic discounting. This was an important turning point in intertemporal choice research as the focus shifted towards what people actually do, and eventually the psychological factors (i.e., mental representations and processes) involved.

2.1.1 DISCOUNTED UTILITY MODEL

The *discounted utility model* (DUM) describes how a reward's value declines exponentially with increasing delay (Samuelson, 1937). Whereas Fisher's model could only be applied to two points in time, the DUM could be applied continuously to all possible points of time in the future. Moreover, it condensed all aforementioned psychological factors into a single *discount rate* factor. Central to this is the idea that discounting is exponential*:*

$$V = Ae^{-kD}$$

where V is the value given to a delayed amount A, which would be received with delay D, and subject to an individual's discount rate k, where high values of k imply a high rate of discounting. e is the exponential constant.

The advantage of exponential discounting is that it assumes individuals discount future outcomes in a consistent, constant manner. Moreover, a number of economists have developed their own axiom systems for the DUM (Koopmans, 1960; Lancaster, 1963; Fishburn, 1970; Meyer, 1976), which contributed greatly to the model's popularity, and it has since been used widely by economists as the normative model of delay discounting. However, even Samuelson himself expressed great caution regarding the model's ability to predict actual human behaviour (Samuelson, 1937).

While justifiable as a normative model of intertemporal choice, it is misapplied as a descriptive one. The assumption that individuals discount future outcomes in a consistent, constant manner is problematic, as several behaviours anomalous to the DUM has been discovered. Regardless, the DUM remains a historically important starting point that models intertemporal choice as an integration of values and delay. Although lacking in any psychological factors, this implies values and delays are processed a certain way, which would influence subsequent, more descriptive models, of intertemporal choice.

2.1.2 A HEURISTICS AND BIASES APPROACH

Although *normative models* of discounting in economics are useful for evaluating how people *should* make intertemporal choices, they fail to capture actual choice behaviour. Because of this, much of the more recent psychological research from the *judgement and decision making (JDM)* field has followed the *heuristics and biases approach* to understand

and describe non-normative deviations from the discounted utility model. This approach has revealed systematic deviations from normative models, so called *biases*, leading to the development of *descriptive models* that can account for this. This has mirrored the development of descriptive theories of other aspects of decision making, such as prospect theory for decision under risk.

Historically, JDM research has mostly concerned itself with decision making under risk, comparing people's judgements and decisions to normative models. While decisions involving risk is a separate research area to decisions involving time, many ideas were developed in this domain that provide context relevant to intertemporal choice research. The normative economics model for decision making under risk, *Expected Utility Theory* was challenged by psychologists Kahneman and Tversky's (1979) *Prospect Theory* in the 1970s. They identified a series of biases that were anomalous to *Expected Utility Theory*, demonstrating how people violate the many logical axioms it relies on.

In short, Prospect Theory describes how losses loom larger than gains, and that people over-weigh small probabilities and under-weigh medium-larger probabilities. This weighting dimension of Prospect Theory is a heavily subjective one, and this shift from objective to subjective weighing is a strong parallel to what has later happened in the intertemporal choice research domain.

The Discounted Utility Model and Expected Utility Theory have in common that they are both normative, rather than descriptive, and both fail to account for a range of anomalous behaviour. This led to the development of more psychologically oriented theories of decision making, such as Prospect Theory for decision under risk. Parallel developments happened in the intertemporal choice research domains. As presented in section *2.1.3,* anomalies to the DUM were identified, and more descriptive models with more subjective utility weightings were introduced.

In both decision involving time, as well as other areas of JDM, systemic deviations from normative models has prompted the development of descriptive models. Many of these models are heuristic models, as biases are often a consequence of heuristics. A heuristic is a mental shortcut which enables people to make snap judgements and decisions without having to continuously stop and contemplate every course of action.

In the 1950s, economist Herbert Simon proposed *bounded rationality* (Simon, 1957), the idea that people had cognitive limitations which consequentially limited rationality. In order to make perfectly rational judgements and decisions, people would have to weigh all costs and benefits, which is not possible given these cognitive limitations, as well as limitations in time and information availability. Thus, heuristics are invaluable in working around these limitations, but they also produce biases that manifest as deviations from normative models.

In sum, this 'heuristics and biases' approach has brought about the aforementioned dichotomy of *normative* and *descriptive* decision making. This dichotomy is used to group the various models of decision making, such as how Expected Utility Theory is classed as a normative model of risky choice, whereas Prospect Theory is a descriptive one. This is parallel to the development that has occurred in the research on intertemporal choice, as will be covered in the next section. While the exponential discounting of the DUM may give a *normative* account of intertemporal choice, it does not *describe* how people actually make intertemporal choices. And so, JDM researchers of intertemporal choice have developed descriptive accounts of intertemporal choice, which will be the focus of the sections.

The relevance of these descriptive accounts is that they are more psychological, making more explicit assumptions about how people mentally process the attributes of each option when making intertemporal choices. Different models of intertemporal choice describe different ways in which the options and their attributes are processed, and these are central to the second strand of research in this thesis. Meanwhile, the next section will cover what can be considered the current *benchmark* of descriptive intertemporal choice models. Although more descriptive, this approach inherits the DUM's about how the values and delays are processed in an intergrative manner.

2.1.3 HYPERBOLIC DISCOUNTING

Earlier I covered the DUM which described how people discount at a constant exponential rate across all magnitudes, signs (gain or loss) and delays. However, similar to how other normative models of decision making (e.g., Expected Utility Theory) have been challenged by empirical findings that people do not act as these models suggest, people do not discount consistently across a number of different attributes. Rather, empirical findings show that discount rates vary with magnitude, delay and sign. Similar to how behavioural data in risky choice could be better explained by descriptive models (e.g., Prospect Theory), the anomalies to the DUM could be better explained by hyperbolic discounting (e.g., *the Hyperbolic Discounting Model*, HDM; Loewenstein & Prelec, 1992; coined by Ainslie, 1975). Hyperbolic discounting assigns a value to each outcome, which is then discounted at a declining rate with delay to the outcome. Like the exponential discounting of the DUM, the outcome with the highest discounted value is chosen, and so the difference between the two functional forms is their shape.

The key difference between exponential and hyperbolic discounting is that time preference will be inconsistent. People are more impatient for the near future but are more patience for longer time periods. Consequentially, they discount more for the near future and less for the distant future. For instance, an individual choosing £100 today over £110 tomorrow might prefer £110 in 100 days over £100 in 99 days, even though each pair of options differ by £10 and 1 day. They avoid waiting more the closer a reward is to happen to the present, and believe that they would want to wait 1 day for an extra £10 in the distant future even though they would not want to do so in the near future.

Exponential and hyperbolic discounting are different *discount functions*. A discount function is the effect of delay upon the subjective value of the outcome, so that an outcome is given less weight the further away from the present it is. Where *F(d)* is the discount function, *d* is delay, i.e., the duration between the present and the time of receiving the outcome. Like the DUM, an individual with a high *k* value someone who is more impatient and discounts more than someone with a relatively low k value. This value is used to calculate the individual's discount rate. The discount function to obtain someone's discount rate is as follows:

$$F(d) = \frac{1}{1 + kd}$$

With regards to *time inconsistency*, suppose an individual with a k value of 0.1 is to choose between £100 in 1 day and £150 in 10 days. The sooner and the later delays can be plotted in the formula as follows, respectively:

$$F(d) \text{ for 1 day} = \frac{1}{1 + 0.1 \text{ x } 1} = \frac{1}{1.1} = 0.91$$

$$F(d) \text{ for 10 days} = \frac{1}{1 + 0.1 \text{ x } 10} = \frac{1}{2} = 0.50$$

To get what £100 is worth in 1 day, we multiply the *discount factor* of 0.91 for 1 day with the smaller-sooner outcome £100 and get £91, and multiplying the discount factor of 0.50 for 10 days with the larger-later outcome £150 and get £75. Because the smaller-sooner option is valuated at £91, which is more than £75, the individual will choose that option and thus discount. Now suppose the same individual with the same k value of 0.1 is choosing between £101 in 100 day and £150 in 110 days. There is still 9 days between the two delays, and £50 between the two outcomes, so according to the DUM the individual should make the same smaller-sooner choice. However, the inclusion of the delay as a denominator in the hyperbolic discounting function changes how the subjective weighing of the outcomes with longer, relative to shorter, delays.

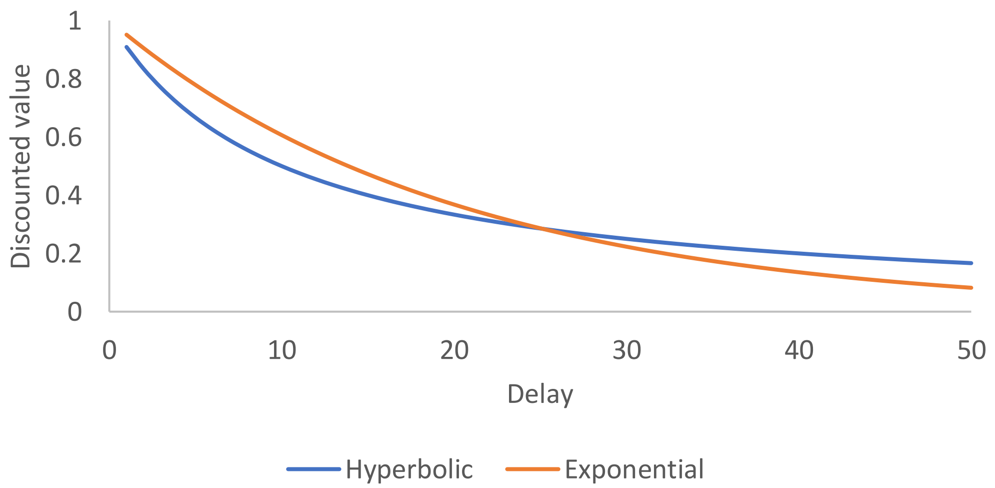
$$F(d) \text{ for 101 days} = \frac{1}{1 + 0.1 \text{ x } 101} = \frac{1}{11.1} = 0.09$$

$$F(d) \text{ for 110 days} = \frac{1}{1 + 0.1 \text{ x } 110} = \frac{1}{12.1} = 0.08$$

As was just done with the shorter delays, multiply each discount factor with the outcome associated with that delay. Multiplying the smaller-sooner outcome £100 with the discount factor of 0.09 for 101 days gives £9, and multiplying the larger-later outcome £150 with the discount factor of 0.08 for 110 days gives £12. Now the smaller-sooner option is worth less to the individual than the larger-later option. At a 110 day delay the original larger-later outcome of £150 is discounted to £12, whereas the smaller-sooner outcome of £101 is discounted to £9 with a 101 day delay.

When presented in a graph the hyperbolic discounting function looks like the one in Figure 2.1, if the individual has a *k* value of 0.1. For instance, while an outcome is worth 100% of its monetary value in 1 day, it drops to £66.7% of that value in just one day. Meanwhile, in 5 days, the outcome is worth 28.6% of its original value but this only drops to 25% of the original value in 6 days. Thus, in 1 day from the present, the outcome is discounted by 33% of its value, but in 1 day from 5 days from the present the outcome only drops by 3.6%. That is, people discount in a time inconsistent manner where the drop in value is steeper in the near future and less steep for the distant future. This hyperbolic discounting behaviour can lead to the preference reversals as described in the example earlier.

Figure 2.1: hyperbolic and exponential discounting.



Note. A graph representation of hyperbolic discounting for an individual with a k value of 0.1, and of exponential discounting for an individual with a k value of 0.05, over 50 units (e.g., number of days, weeks, months or years) of delay. The y-axis shows the proportionate value of the outcome at a given time on the x-axis out of the original outcome.

2.1.3.1 ANOMALIES TO THE DUM

As noted earlier, hyperbolic discounting better describes behavioural intertemporal choice data than the DUM. There are a number of documented anomalies to the DUM that can be accounted for by hyperbolic discounting in general, or specifically by Loewenstein and Prelec's HDM. Regardless, these anomalies highlight the difference between what traditional economics have *prescribed* and what people actually do, and thus the need for descriptive or even psychological accounts.

First, *the common difference effect* (Loewenstein & Prelec, 1992) is when people discount less for longer delays than they do for shorter delays. An example of this is a preference reversal where someone who prefers £100 in 1 month over £150 in 4 months, prefer £150 in 12 months over £100 in 9 months. According to exponential discounting it should not make a difference that both options have been shifted 8 months into the future. The DUM, and exponential discounting in general, posits that people discount *consistently* over time, and so it cannot account for this effect. However, this fits with the hyperbolic model as it describes less discounting for longer delays.

Second, Thaler (1981) identified *the magnitude effect* (Thaler, 1981; Ainslie & Haendel, 1983; Loewenstein, 1987; Benzion, Rapoport & Yagil, 1989; Holcomb & Nelson, 1992; Loewenstein & Prelec, 1992; Green, Fry & Myerson, 1994; Kirby, Petry & Bickel, 1999). This is when a person discounts less for larger amounts than they do for smaller ones. An example of this would be an individual who is indifferent between £100 in 1 month and £150 in 4 months but prefers £1,500 in 4 months over £1,000 in 1 month. The magnitude effect is inconsistent with the DUM, which holds that discount rates are independent of outcome magnitude. In the HDM, the delay is multiplied with the value of k, which often varies for vastly different amounts. For instance, the k value for £10 might be 0.1, whereas the k value for £1000 might be 0.001. Thus, this value captures both characteristics of the individual as well as characteristics of the stimuli.

Another anomaly, known as *the sign effect* or *gain-loss asymmetry* (Mischel, Grusec and Masters, 1969; Yates and Watts, 1975; Thaler, 1981; Loewenstein, 1987; Benzion et al., 1989; MacKeigan et al., 1993; Loewenstein & Prelec, 1992; Redelmeier and Heller, 1993), is when people discount less for losses than they do for gains, across the same interval. An example of this is when an individual who is indifferent between receiving £100 in a month and £150 in 4 months, yet they choose to pay £100 in 1 month instead of paying £150 in 5 months. The reason they would choose to not receive £50 in the gain scenario, but would choose not to part with £50 in the loss scenario is that in the latter case the £50 is a loss that they would have to part with. It violates DUM, because the model says someone's discount rate should be independent from the sign (+/-) of the discounted values. Again, the answer lies in the *k* value of the hyperbolic discount function of the HDM, as the *k* value is different for gains and losses.

The magnitude effect and *the sign effect* are something that the DUM cannot and the HDM can account for specifically. It is however possible for other exponential discounting models to incorporate the parameters that differ according to magnitude and sign, so that they too can accommodate for the two effects. These two DUM anomalies nonetheless highlight the difference between normative and descriptive discounting, and the contribution of a psychological approach. This is further highlighted by the final anomaly, the delay-speedup asymmetry.

The *delay-speedup asymmetry (*Lowenstein, 1988) is when there is an asymmetry between speeding up and delaying the receipt of the positive outcome (reward). The amount an individual might demand in order to compensate for delaying the reward ranges between 2 to 4 times greater than the amount they are willing to pay to speed up the receipt, across the same interval. The two choice scenarios (speedup and delay) represent the same options, and should, according to the DUM, be discounted at the same rate. However, because the HDM incorporates the *reference-dependence* aspect from Prospect Theory (Kahneman and Tversky, 1979), it can account for these findings.

Reference-dependence means that the value people place on options are based on whether people perceive them as gains or losses in relation to a *reference point*. Because losses loom larger than gains, people experience *loss aversion*, meaning they are more inclined to avoid losses than pursue gains. In the *delay* scenario they feel they already own the smaller-sooner option, so that becomes their reference point where anything less is experienced as a loss. The loss of delaying this outcome looms larger than the gain in monetary value they get by delaying the receipt. However, in the *speedup* scenario, the larger-later option becomes the decision maker's reference point, so they require more money to part with the delayed outcome to compensate for the loss relative to the reference point. In either scenario, the first option becomes the reference point from which the loss on one dimension (monetary or temporal) looms larger than the gain on the other dimension, making people unwilling to trade. This shows how the use of psychological principles and subjective value makes the HDM a more descriptive one than the DUM.

Hyperbolic discounting is in itself a DUM anomaly. That is, the notion that discount rates decline over time is inconsistent with the DUM. Further, hyperbolic functional forms fit intertemporal choice data better than the exponential functional form of DUM do (Kirby, 1997; Kirby & Marakovic, 1995; Myerson & Green, 1995; Rachlin et al., 1991). In other words, choice data show declining discount rates rather than constant discount rates. Thus, while the DUM might be a normative theory in the sense that it describes how to discount consistently, hyperbolic discounting is a better descriptive data as it fits the data better.

2.1.3.2 CONTIRUBTION OF HYPERBOLIC DISCOUNTING

The main contribution of the hyperbolic discounting is the idea that people discount more for the near future and less for the more distant future. This time inconsistency leads to demonstrable preference reversals, such as an individual choosing a smaller-sooner option over a larger-later option for shorter time intervals, yet choosing the larger-later option for the distant future, when the monetary options are the same and the two times of receipt are equally many days, weeks or months apart.

The idea that the relationship between delay and value is hyperbolic is now largely accepted amongst psychologists and economists alike. Hyperbolic discounting fits behavioural data better than the DUM, as it can account for the DUM anomalies outlined above, whilst retaining a lot of the simplicity of the DUM. Despite the gained popularity of hyperbolic discounting, proponents of the DUM have criticised the behavioural findings that supports hyperbolic discounting for largely relying on hypothetical rewards (Wilkinson & Klaes, 2017). The common argument is that this leads to unreliable results as incentives are not as strong as that of real monetary rewards. However, Madden and colleagues (2003) found no significant differences in discounting between real and hypothetical rewards. Both data sets fit a hyperbolic discounting function better than an exponential one.

A second common criticism is that decisions makers are not usually provided with any information about annual interest rates (Wilkinson & Klaes, 2017). People are simply presented with a choice- or a matching task between a smaller-sooner and a larger-later sum of hypothetical money. However, one might argue that the everyday decision maker is usually not provided with interest rates with most intertemporal choice they make on a day to day basis either. It is not realistic to expect that decision makers contemplate interest rates as they choose between a delicious dessert or sticking to their long term diet plan, for instance.

Like the DUM, hyperbolic discounting integrates the attributes of each option, by weighing the outcome by its delay, before options can be compared. This implies that people *mentally process* the options and their attributes as such, which is relevant for the next section as well as this thesis' second strand of research. In sum, hyperbolic discounting is more descriptive of people's actual intertemporal choice behaviour the exponential DUM. However, there are still discounting behaviours that are anomalous to both hyperbolic discounting and the DUM. This will be further outlined in the next section.

2.2 MODELS

So far, I have covered the background history of discounting model, from the economically normative and simple discounted utility model, to the more descriptive yet still algorithmically simple hyperbolic discounting model. Both the DUM and hyperbolic discounting describe how outcomes are weighted by delays first, but the hyperbolic discounting fits behavioural data better than exponential discounting. Nonetheless, hyperbolic discounting fails to account for interval effects that, according to either model, should not affect time preference. This section will go through a number of alternative models to the aforementioned discounting models that offer an alternative to the idea that amounts are weighted by delay.

2.2.1 INTERVAL EFFECTS

Among the interval effects that challenge the aforementioned discounting models are the interval effects of subadditivity (Read, 2001) and superadditivity (Scholten & Read, 2004). These effects violate the assumption of *additivity in intervals*, held by both exponential and hyperbolic discounting. The assumption holds that total discounting over a given interval should be indifferent to whether and how that interval is subdivided. The effects are seemingly mutually exclusive. Whereas subadditivity is when a given interval is subdivided into shorter intervals and this leads to *more* discounting than for the undivided interval, superadditivity is when the subdivision of this interval leads to *less* discounting. It appears that interval subdivision leads to *more* discounting up to a certain point with increasing number of subdivisions, and beyond this point interval subdivision leads to *less* discounting.

Consider an interval spanning from 1 month to 6 months into the future. This can be subdivided into two intervals, one from 1 month to 3 months, and one from 3 months to 6 months. Consider an individual who prefers £500 in 6 months over £100 in 1 month, yet when you subdivide the intervals, they exhibit subadditivity (Read, 2001), by preferring £100 in 1 month, over £250 in 3 months, and £250 in 3 months over £500 in 6 months. Conversely, if they prefer £1,000 in 1 month over £1,500 in 6 months, they show superadditivity (Scholten & Read, 2006) if they prefer £1,500 in 6 months over £1,250 in 3 months, and £1,250 in 3 months over £1,000 in 1 month. These interval effects will be described in more depth in the next sections.

2.2.2 OPTION- VS. ATTRIBUTE-BASED MODELS

The exponential and hyperbolic discounting models discussed so far are both *alternative / holistic / option-based* models. These models describe how people evaluate each option, by first evaluating each option in isolation, considering only the attributes of that option, to form a *holistic* subjective value of that option (Payne, Bettman & Johnson, 1988). The decision maker forms these subjective values for each of the options in the choice context before comparing the options based on these values. Traditional economic models tend to fall into this category. For instance, the two traditional economic models covered earlier in this chapter, Subjective Expected Utility and the Discounted Utility Model, both weigh outcomes by either risk or delay, respectively. For instance, the DUM describes how an option is evaluated in isolation, based on its two attributes: outcome and delay, forming a discounted utility of that option. Then the next option is evaluated based on its two attributes, forming a discounted utility. Once all options have been evaluated, the option with the greatest discounted utility is chosen. In short, values are assigned to the outcomes, discounting these values as a function of their associated delays, and choosing the option with the highest discounted value.

In addition to option-based models, there are also *dimensional* / *attribute* based models. Here, options are compared along each attribute, and people choose based on how each attribute in one option differs from the same attribute in the other option (Payne, Bettman & Johnson, 1988). In other words, attributes are considered first, and the difference on one attribute dimension is compared with the difference in another attribute dimension. While option-based models evaluate an option first, based on its attributes, and then go on to evaluate the next option based on *that* option's attributes, attribute-based models evaluate an attribute first, based on the differences for each option, and then goes on to evaluate the next attribute. In short, options are compared along each attribute.

Consider an attribute-based model in a typical binary delay discounting task with a smaller-sooner and a larger-later monetary option. The decision evaluates each attribute in turn. The smaller and the larger monetary outcomes are compared with one another, and the sooner and the later delay are compared with one another. Option- and attribute-based models are on a continuum, and in a full attribute-based model, the differences in the delay attribute is traded off with differences in the outcome attribute. Depending on the specifics of the attribute-based theory, the decision maker chooses the option that is favoured in this tradeoff.

A key distinction between attribute- and option- based models is whether people consider options in isolation first (option-based), or whether options are first compared along each attribute (attribute-based). The following sub-sections will outline 4 examples of attribute-based models of intertemporal choice; *the interval discounting model* (Scholten & Read, 2006), *the tradeoff model* (Scholten & Read, 2010), *the DRIFT model* (Read, Frederick & Scholten, 2013) and *the ITCH model* (Marzilli Ericson et al., 2015). The interval discounting model and the tradeoff model both aim to account for a range of *interval effects*; where people's discounting differ depending on whether a given interval is undivided or divided into segments. The DRIFT model and the ITCH model are heuristic-based models that focus on how different framings of the different options lead to different choices.

2.2.3 INTERVAL DISCOUNTING MODEL

Some attribute-based models of intertemporal choice have been introduced to account for one anomaly to the DUM that the HDM cannot. One such model is the *interval discounting model* (also known as *discounting by intervals*), which was introduced to account for the observed DUM anomaly called *subadditivity* (see section 2.2.1). One assumption shared by all option-based discounting models is that of *additivity*; that how much an outcome is discounted should be independent of whether the interval is subdivided or not. According to option-based discounting models, the extent to which an individual discounts over a whole undivided year should not be any different than over the subdivided winter, spring, summer and autumn. If the discounting that happens over the course of each of these four segments is added together and yield the same result as the discounting over the whole year, then discounting is additive.

However, empirical evidence of intertemporal choice behaviour shows systemic violations to this assumption, known as subadditivity (Read, 2001, Read & Roelofsma, 2003, Scholten & Read, 2006) and superadditivity (Scholten & Read, 2006). Subadditivity is when an individual discounts less over an undivided interval than over its sub-divisions. Discount rates are higher the closer together the two outcomes are, and this is incompatible with discounting models where the utility of an outcome is discounted by its delay.

Consider one example from Scholten and Read (2010) where they had participants chose between (A) $100 in 19 months and (B) $118 in 22 months in one trial, and in another trial choose between (C) $100 in 16 months and $136 in 22 months. Most of the participants preferred the smaller-sooner (A) over the larger-later (B), but most also preferred the larger-later (D) over the smaller-sooner (C). In this example, the 6 month interval in (C) and (D) from 16 months to 22 months is effectively split into two sub-intervals of 3 months for (A) and (B) where they only discount over the last half of the interval, from 19 months to 22 months.

The people who chose (A) over (B) gave more weight to the negative of the 3 month waiting time between (A) and (B) more than they valued the positive of the extra $18 they would get for the wait. According to the sensitivity to more proximate than more distant delays, the difference between a 19 month wait and a 22 month wait should not be as bad to the decision maker as the wait between a more proximate 16 months and 22 months. Hence, someone choosing (A) at 19 months over (B) at 22 months should choose (C) at 16 months over (D) at 22 months as well according to the HDM, but instead there is a sudden switch from preferring the smaller-sooner for A-B to the larger-later for C-D. This is Subadditive discounting, because there is more discounting over a sub-segment of the total interval than there is for the total interval.

Another observed violation of the assumption of additivity is *superadditivity*, where an individual discounts *more* over an undivided interval than over its sub-divisions (Scholten & Read, 2006). Again, consider another example from Scholten and Read (2010) where participants chose between (A) $8,250 in 12 months and (B) $10,250 in 24 months in one trial, (C) $6.250 in 12 months and (D) $10,250 in 36 months in another trial, and in yet another trial between € $4,250 in 12 months and $10,250 in 48 months. The total interval here is between (E) 12 months and (F) 48 months, and how most participants preferred the smaller-sooner (E) over the larger-later (F). For the sub-interval C-D most people preferred the smaller-sooner (C) over the larger-later (D), but for the smaller sub-interval A-B, most people preferred the larger-later (B) over the smaller-sooner (A).

The person choosing (B) over (A) values the negative of the 12 month waiting time between the two options *less* than they value the positive of the $2,000 extra they get for waiting. Because the HDM describes how people's sensitivity to delay decreases with greater delay, one would expect even *less* weight to be put on greater delays, and thus even less discounting. More broadly, there are no general models of discounting in which sensitivity to delay increases with delay. Thus, the difference between waiting 12 months and waiting 24 months is worse than the difference between waiting 24 months and 36 months or 48 months. However, most people chose the smaller-sooner (C) at 12 months over the larger-later (D) at 36 months, and the smaller-sooner (E) at 12 months over the larger-later (F) at 48 months. This switch from preferring the larger-later for the sub-interval to preferring the smaller-sooner for the total interval means they are discounting more over the 24 months interval and the 36 month interval than they do for the two or three sets of 12 month sub-intervals.

The phenomenon of superadditivity may appear at odds with subadditivity, but these two *interval effects* are actually compatible, and form a pattern: Discounting is greater over the sub-divisions than the sum of the total interval (subadditivity) up to a point with increasing interval length, and beyond this point discounting is less over the sub-divisions than for the whole interval combined (superadditivity).

From observing these interval effects of subadditivity and superadditivity, Scholten and Read (2006, 2010) argued that the decision makers must be employing some form of *attribute* based valuation, because only by comparing the two temporal attributes can you determine the interval. Both of these forms of *nonadditive discounting* suggest that the outcomes are not just discounted as a function of the delays from the presence *to* the receipt of those outcomes, but as a function of the interval *between* the receipt of two options. Hence, if discounting of the outcomes depends on the interval between the two options, then this means the decision maker is making a direct comparison between the two intervals. In other words, they are making attribute-based comparisons.

The Interval Discounting Model (Scholten & Read, 2006) retains the option-based evaluation of discounted values seen in DUM and hyperbolic discounting, but also introduces attribute-based comparisons in how people evaluate delays. That is, people make direct comparisons across the temporal attributes but not for the outcome values. While this model can accommodate for subadditivity and superadditivity, it cannot accommodate for the interaction effect observed between intervals and compensations. That is, subadditivity occurs when the intervals are long relative to the compensations, whereas superadditivity is when the compensations are large relative to the intervals (Scholten & Read, 2010). This is called *relative nonadditivity* and in order to be accommodated for it needs a model of both time *and* outcome attribute comparisons.

2.2.4 THE TRADEOFF MODEL

The aforementioned interval discounting model makes a departure from traditional discounting models which assume that people discount the value of delayed outcomes, assigning a discounted value to each outcome, choosing the one with the greatest discounted value. The interval discounting model enables for direct comparisons between the delays of each option, but not of the outcomes of each option. Hence, it is only partially attribute-based and partially option-based.

The *tradeoff model* (Scholten & Read, 2010), however, not only describes temporal attribute comparisons, but it is completely attribute based, meaning that it describes intertemporal choice as comparisons between along *both* time and outcome attributes. In other words, it is like the interval discounting model in that delays are directly compared, but it is different in that outcomes can also be compared to one another. In the tradeoff model, people weigh how much more they will receive if they wait more *against* how much they will have to forgo if they do not wait as long. Thus, while option-based discount models, like the HDM or the DUM, weigh options *by* time, the fully attribute-based tradeoff model weigh outcomes *against* time. Options are compared along each attribute: time and outcome, and the option favourited by this comparison is chosen.

As mentioned in the previous section, the tradeoff model can accommodate for *relative nonadditivity*, which the interval discounting model cannot. There are two forms of relative nonadditivity. *Relative subadditivity* is when outcome differences are *small* relative to the temporal differences between the two options, whereas *relative superadditivity* is when outcome differences are *large* relative to temporal differences between the two options. For relative superadditivity, the larger-later option is chosen over the interval's sub-segments, but the smaller-sooner option is chosen over the whole interval, whereas for relative subadditivity the smaller-sooner option is chosen over the sub-segments and the larger-later option is chosen over the whole interval.

The key difference between the interval discounting mode land the tradeoff model is that the interval discounting model cannot account for relative nonadditivity, because it comes down to the *relative* differences in outcomes and differences in intervals. Only the tradeoff model allows for direct comparisons between the outcomes, so that differences between the two can be judged, because this model is fully attribute-based, comparing options along both the time- and outcome-variables.

2.2.5 THE DRIFT MODEL

Another attribute-based model is the *DRIFT* model (Read, Frederick & Scholten, 2013) which describes how the framing of choices influence intertemporal choice. The absolute (D)ifference between two outcomes are given more attention in *amount frames*, such as conventional delay discounting tasks (e.g., "receive £100"), whereas the (R)atio between the two outcomes are given more weight in *interest-total* frames (e.g., "receive 50% more in total"). The exponential (I)interest rate is given more weight in *interest-rate frames* (e.g., "receive 10% per year"), and as for (F)inance, whether an offer is described as a consumption or an investment choice is enhanced by the *investment frame* (e.g., "receive" vs "invest"). The difference, ratio, interest and finance (DRIF) features are traded against the (T)ime until which they receive the larger reward. If the DRIF outweighs T, an individual will choose the larger-later option, but if time is given more weight, they choose the smaller-sooner option.

The DRIFT model is an aim to provide a framework for context effects to discounting, such as *the hidden/explicit zero effect* and the *date/delay* effect, as week as the finding that people discount less when the conventional delay format (e.g., number of years to receiving the outcome) was written as the age of the decision maker at the time of receipt (Frederick, Read, LeBouef, & Bartels, 2011). To recap, the hidden/explicit zero effect is when discounting is reduced when the decision maker is reminded that choosing the smaller-sooner option means you get nothing later, and choosing the larger-later option means you get nothing sooner (Magen, Dweck & Gross, 2008). The date/delay effect is when people discount less when delays are written as calendar dates instead of the conventional delay format (Read et al., 2005).

2.2.6 THE ITCH MODEL

Yet another attribute-based model of intertemporal choice is ITCH (Marzilli Ericson et al., 2015), short for *intertemporal choice heuristic model*. It is closely related to the DRIFT model, describing how people use simple arithmetic heuristics when deciding between smaller-sooner and larger-later options. In a simple smaller-sooner versus larger-later monetary delay discounting task, the simple arithmetic comparisons, like division and subtraction, are made along each of the attribute dimensions: outcome value and time until receipt. The ITCH model describes how people compare these two options in terms of their pros (larger and sooner) and cons (smaller and later). The arguments for and against choosing either option are compared using a weighted combination that results in the probability of being chosen for each option.

The ITCH model shares with both DRIFT and the tradeoff model that it does not generate a discounted value for each option that results from multiplying a discount function and a value function. In particular it shares with DRIFT a absolute comparison for delays, but it differs in that it also includes a *percentage* comparison as well, which allows for relative comparisons between the outcomes. In sum, the model describes how decision makers compute a weighted sum of 4 variables: The absolute (1) and relative (2) differences in magnitude between the options, and the absolute (3) relative (4) differences in time between the options.

Marzilli Ericson and colleagues (2015) fitted the intertemporal choice behaviour data to the attribute-based models ITCH, DRIFT and tradeoff models, as well as option-based discounting models such as HDM and DUM. Participants were presented with different framings of the same smaller-sooner vs. larger-later choice task, They found that the attribute-based models fit the data better than option-based models, and that out of all the models the ITCH best predicted the choice data. Thus it appears that instead of generating discounted values for each option, people apply simple heuristics to make intertemporal choices that are adequate for their given situation.

Because the DRIFT and ITCH models include weighing parameters for different variables, they have the potential to account for how contextual affects what people attend to in the choice scenario. Moreover, they are based on the well-documented psychological concepts of reference-dependence (Kahneman & Tversky, 1979) and attribute-level comparison (Tversky, 1972). Where traditional option-based discounting models of intertemporal choice fall short, these psychological attribute-based models can better account for context effects on intertemporal choice behaviour. The various context effects provide clues about how options are mentally represented, and the models help us understand why the framing affects preferences. No model perfectly account for the data, but these attribute-based models account for more, albeit these models are also algorithmically more complex. Nonetheless, option-based models remain widespread in the academic literature.

2.2.7 SUMMARY

This section has covered some of the many models of intertemporal choice that focus more on attributes than on options. The traditional economic discounting model *discounted utility model* (Samuelson, 1937) prescribes a weighting of each option by its given delay. This means people are judging the options separately in turn, first the discounted utility of one option is generated by weighing that option's amount by its delay, then the same is done for the next option, and the option with the greatest discounted utility is chosen. The *hyperbolic discounting model* (e.g., Loewenstein & Prelec, 1992) is in this regard the same as the discounted utility model, as each option is also judged in isolation before they are compared to one another. The main difference is the steeper discount rates for the more immediate future.

Alternative-based models like *the interval discounting model* (Scholten and Read (2006), *the tradeoff model* (Scholten and Read, 2010), the *DRIFT model* (Read, Frederick & Scholten, 2013) and *the ITCH model* (Marzilli Ericson et al., 2015) argue that options are directly compared along one or both attributes. In the interval discounting model, the delays of each option are compared across options, but in the tradeoff model the values of each option are *also* compared across options. This makes the interval discounting model strictly speaking a hybrid model between attribute- and option-based options, whereas the tradeoff model is a fully attribute-based model. The DRIFT model and ITCH model take the attribute-based notion further, incorporating psychological principles that have been sorely lacking in the more economic models of intertemporal choice.

In this thesis, I am interested in the mental processing underlying intertemporal choice. The comparison of options across each attribute-dimension suggest an entirely different mental process to that of weighting values by delays for each option in isolation. These processes may reflect different strategies used in different choice frames. For instance, people might be making more attribute-based comparisons in conventional delay discounting tasks, but shift more towards an option-based process when the delays are written like calendar dates (see Read et al., 2005). Option-based models are often referred to as *holistic* models, and perhaps being reminded of the specific calendar dates of when the decision maker will receive their reward, they mentally represent the option in a more holistic manner that contains both the delay and the outcome in an integrated manner. For similar reasons, people might shift from an attribute-based processing strategy to a option-based strategy when delays are accompanied by verbal reminders of the decision maker's personal plans for the time of receipt (Peters & Büchel, 2010). These issues will be explored further in Chapter 4 of this thesis.

2.3 CONSTRUCTION OF PREFERENCE

So far, I have traced the development of discounting models from normative theories through theories that introduce more subjectivity to the valuation of probability, gains, losses and delay. Although hyperbolic discounting can account for a range of anomalies to the normative models, the valuation process is still described as though people look up values on psycho-economic functions. Hence, people's preferences should still be stable over time, or even multiple repetitions of the same choice. Crucially, preference should be entirely determined by the options presented, rather than by factors deemed irrelevant by the normative models. Yet, the research described in this section demonstrates that this is not the case, suggesting that the way in which people mentally represent and process intertemporal choices are subject to factors that influence their time preference.

Further development in the field of JDM has led to the more radical notion that preference is constructed, unstable and context dependent, being affected by numerous normatively irrelevant factors (Slovic, 1995). The review titled *The Construction of Preference* by Payne, Bettman and Johnson (1992) argued that this idea of the JDM literature in the preceding two decades, as it contested the assumption, from economics, that preference is a stable trait. It has also challenged the assumption that preferences follow certain principles like *time consistency*. But as seen earlier in this chapter, this does not describe people's behaviour as they behave in very time inconsistent manners. The same goes for preference, which appears to be constructed (Slovic, 1995).

Preferences are said to be *constructed*, as opposed to stable internal traits that are revealed during choice tasks, so that different choice environment lead to different preferences (Bettman, Frances Luce & Payne, 1998). Instead preferences are formed spontaneously as decisions are being made, and can be influenced by the choice context, how the options are described, and the method used to elicit preferences. Preference formation can be influenced by the choice context, as some alternatives are framed differently (e.g., '90% success rate' versus '10% fail rate'), or how adding a third alternative changes people's choice in a binary choice task (Simonson & Tversky, 1992). Differences in the task can also influence preference formation, for instance if one is asked to rate two options rather than choose one of them (Slovic 1995). [1]

Much of the research that led to the notion that preference is constructed is, again, found in the study of risky choice. For instance, one assumption traditional rational economic theories hold is the principle of *invariance* (Tversky & Kahneman, 1986), holding that preference is independent of the way choice options are described (*description invariance*), or of the way in which preference is elicited (*procedure invariance*). However, consistent with the notion of preference being constructed, empirical evidence of people's choice behaviour show that both these assumptions of variance are violated, as preferences are sensitive to both how options are described and to response mode (Fischhoff, Slovic & Lichtenstein, 1980; Kahneman & Tversky, 1979; Tversky & Kahneman, 1981, Slovic; 1995). These findings of contextual effects in risky choice mirror what has since been found in the delay discounting research literature, as will be discussed next.

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[1] As a side note, the psychological notion of mental construals is also based on the idea that judgements and decisions are constructed. This is something that will be discussed further in the next chapter, but it is worth mentioning here as both rest on the idea that judgement formation are influenced by what most easily comes to the individual's mind (Higgins, 1996). This can be the immediate choice context or salience, such as when an individual's judgement of life satisfaction is influenced by whether or not they were asked to give a judgement of their marital satisfaction previously (Schawrz, Strack & Mai, 1991). Likewise, mental construals can be affected by the temporal context, as we think of the near and distant future differently (Atance & O'Neill, 2001; Liberman & Trope, 1998).

2.3.1 CHANGING OF DISCOUNT RATES

The emerging consensus in the JDM research literature appears to be that preferences are subject to contextual effects from the choice environment or characteristics of the choice task and how the options are described (Lichtestein & Slovic, 2006; Simonson, 2008). There are a number of contextual effects in the delay discounting literature that supports this idea. Factors that should be irrelevant to preference according to normative theories turn out to affect time preference a great substantially.

2.3.1.1 HIDDEN / EXPLICIT ZERO EFFECTS

An example of contextual factors that should be irrelevant to discount rates, according to normative theories, is the case of *hidden / explicit zero effects* (Magen et. al., 2008). With both real and hypothetical money they asked some participants if they would have $5.00 today or $5.20 in 26 days, a conventional delay discounting task. They asked other participants if they would rather have $5.00 today and $0 in 26 days or $0 today and $6.20 in 26 days. This condition discounted less than the former condition. By making it explicit that they would get *zero* money in the future if they went with the smaller-sooner option, participants were more likely to choose the larger-later option.

The interpretation of this study is that the smaller-sooner option looked less appealing when the unpleasant future consequence of that choice was made explicit (Radu et al., 2011). In support of this, the subjective value of the smaller-sooner option dropped significantly when zeros were made explicit, but people did not value the larger-option any less than when there was no explicit zeros (Magen et al., 2014).

2.3.1.2 OPTION SKEW

A second example of contextual influences on time preference, is the Stewart, Reimers and Harris (2014) study on *option skew*. Participants chose between smaller-sooner and larger-later amounts of money, in which the values were £100, £200, £300, £400 and £500. Some participants were given delays of 1 day, 2 months, 4 months, 8 months, 10 months and 12 months. That is, the delays were spread apart in a uniform fashion. Meanwhile, other participants were presented with the delays 1 day, 2 days, 1 week, 2 weeks, 1 month, 2 months, 6 months, and 12 months. That is, there were a positive skew of distribution, with far more shorter delays than longer ones. This made the longer delays seem like they were much further way than in the uniform distribution and resulted in people discounting more. Even though both conditions were presented with the same amounts delivered 12 months into the future, this amount was valued a lot less in the positive skew condition than in the uniform condition. The above findings substantially challenge the prevalent idea that decision makers hold stable internal discount rates. However, Alempaki and colleagues (2019) replicated the findings by both re-analysing the original study as well as new experiments and offered some more modest interpretations of the effect, as the magnitude of the effect in their study was much reduced, suggesting it was not as strong as previously assumed and possible an artifact of the design.

2.3.1.3 EMOTIONS

Emotions can, much like contextual factors, also influence discounting. Like context effects, emotions should not affect preference if it is internal and stable as per rational economic models. However, numerous studies show that different states of emotion can lead to different temporal preferences. Lerner, Li and Weber (2013) had participants watch video clips to induce certain emotions. In the sadness condition participants watched a video about the death of a boy's mentor, the disgust condition a video of an unsanitary toilet, and the neutral condition a video about the Great Barrier Reef. Following this, participants wrote an essay about a time they felt sadness or disgust, or about a neutral activity, depending on condition. Results showed that those induced to feel sad discounted more than those made to feel disgust, and those in the neutral condition. The authors argued that sadness led to a *myopic* focus on obtaining money *now* versus *later*, making people more short-sighted in their financial decisions.

The above conclusion was also supported by Guan and colleagues (2015) with *affective negative priming*, which involved showing participants pictures that were either negative (fear related), positive (happiness related) or neutral. In a subsequent delay discounting task, those viewing negative pictures chose more smaller-sooner options over larger-later ones. In a subsequent time reproduction task, participants were to press a button after the duration they deemed a stimulus had been on screen for. Here, the participants in the negative emotion condition were significantly faster than the other conditions, suggesting that the negative emotional priming made them overestimate time. This also supports the idea of myopic decision making, and that this was linked with discounting more when delays feel longer as a result of negative emotions.

An explanation of why negative emotions lead to more discounting can be found in the *appraisal tendency framework* (Lerner & Keltner, 2000). Here, specific emotional states generate tendencies towards specific actions which allow an individual to manage the present circumstances. For instance, in the study by Lerner and colleagues (2013), the induced sad affect made people more impulsive in the subsequent delay discounting task, which may have been their way of seeking an instantaneous way to counter their negative mood (Lempert & Phelps, 2016). However, it is worth noting that there is also evidence that viewing positive emotional images prior to engaging in delay discounting tasks lead to more smaller-sooner choices (Li, 2008; Van den Bergh, deWitte & Warlop, 2008; Kim & Zauberman, 2013; Wilson & Daly, 2004).

2.3.1.4 DATE/DELAY EFFECT

The traditional economic principle of invariance, specifically description invariance, holds that an individual should have the same preference no matter how the options are described. Hence, in a conventional delay discounting task, it should not matter if delays are written as the number of months to the time of receipt, or as the specific calendar dates. However, behavioural evidence show that people discount less when delays are given in specific dates rather than the more commonly used delay format. In other words, people were more inclined to wait for a monetary reward to be delivered on “3 September 2021” than “in 3 months" even if that was the same temporal distance from the present (Read, Frederick, Orsel, & Rahman, 2005).

The researchers had participants choose between smaller-sooner and larger-later options, but some participants had the delays described to them as the number of months, some as the number of weeks, and some as the specific calendar date. While there was no significant difference in discounting between the week condition and the month condition, the date condition significantly differed from the other two conditions. Participants chose more larger-later options when viewing the same delays as in the week and month conditions, but in a calendar date format. The effect was replicated in a *matching task* (where people had to fill in e.g., "$370 in __ weeks is equal to $450 in 36 weeks) and for actual rather than hypothetical money (using a random lottery for some of the choices made). When delays were described as *both* number of months and dates in conjunction people discounted at the same rate as when delays were *only* described as number of months. In other words, the attenuating effect of date-format upon discounting disappeared when people were presented with how long they would have to wait, and choice data was only consistent with hyperbolic discounting when delays were written as number of months.

The findings suggest that the date format, in the absence of numerical delay, makes people more patient. This framing effect has been known as the date/delay effect. While the specific mechanisms behind this effect are unknown, one possibility is that when an individual see dates, rather than delays, they are more likely to episodically (see upcoming Chapter 3) represent that point in time. Whereas for the delay option, people simply think of the delay in terms of its distance from the present; in other words, how long they have to wait.

Read and colleagues (Read, Frederick, Orsel & Rahaman, 2005) offered five potential explanations for the date/delay effect. First, they suggested that the date-framing make people focus their attention more on amounts. And so, people choose the larger-later option due to the greater amount. Second, they proposed that the delay- and date-framing lead to different choice strategies. For delays, people can form an exchange rate between amounts and delays as these are both continuous numerical variables. However, for dates this is not possible (unless people convert dates to delays), so people simply choose the option that is superior on the most important variable (amounts). The problem with the above two explanations is that neither can explain the results from the matching task, as this does not permit such decision strategies.

Thirdly, it could be that decision makers preferred the precision of dates, and that the greater certainty made them more patient (Read et al., 2005). This is however problematic, as both options are either presented as dates or delays, and so the smaller-sooner option is no more or less certain than the larger-later option in either frame. This explanation also fails to explain how showing both delays and dates simultaneously led to the same results as the delay-frame, as the presence of dates should have given decision makers the same sense of certainty as dates alone, and thus lead to the same attenuated discounting behaviour as in the date-frame.

Fourthly, the date-frame might have prompted people to underestimate the interval between the two delays (Read et al., 2005), forgetting that, say, there is an entirety of 20 weeks between the 16th of January and the 4th of June. Finally, the fifth potential explanation offered was that two dates might be judged as more similar to one another than two delays, even though they span over the same interval. Although both of these explanations can account for the matching task results, the latter also fits well with the finding that only the delay-frame led to hyperbolic discounting. This explanation is based on the argument by Rubinstein (2003) that people discount hyperbolically because delays are judged as more similar with greater delays. For instance, 11 and 12 months feel more similar than 1 month and 2 months, so people discount more steeply for the near future than they do for the distant future. These latter two explanations are interesting for the wider theme of this thesis, because they suggest that temporal framing may affect more than valuation, but more broadly how people mentally represent the future.

2.3.2 IMPLICATIONS

The previous section outlined a number of contextual effects on delay discounting, which cannot be accounted for by neither the normative DUM or the more descriptive hyperbolic discounting, as these assume people have stable time preference. Even though hyperbolic discounting could account for many of the anomalies outlined in section 2.1, where the DUM could not, hyperbolic discounting is not a radical change from discounted utility. It still assumes people weigh outcomes by delays, thus presuming people are mentally looking up some internal discount factor, or at least the equivalent of that.

The DUM gained its normative status largely because of its simplicity, reducing discounting down to a simple exponential discount factor. In the same manner, hyperbolic discounting has the per-period discount factor of δ, producing a hyperbolic shape instead of an exponential one. Hence, criticisms of hyperbolic discounting is not usually form proponents of the DUM, but rather more radical models (Wilkinson & Klaes, 2017).

Many of these models can be classed as *attribute-based discounting models*, such as those described in section 2.2 (IDM, Scholten & Read, 2006; Tradeoff, Scholten & Read, 2010; DRIFT, Read, Frederick & Scholten, 2013; ITCH, Marzilli Ericson et al., 2015). Conversely, models like the DUM and hyperbolic discounting can be classed as *option-based discounting models*. In short: option-based models weigh outcomes by delays before options can be compared, and attribute-based models compare attributes directly across options. They represent different accounts of how options and their attributes are *mentally processed*.

Meanwhile the contextual effects outlined in this section highlights the potential role of *mental processes* in intertemporal choice. These mental representations can make decision makers more or less patient either from contextual factors or from individual differences in mental representations. The next section describes how these *relatively* stable individual discount rates varies greatly across individuals, and the next chapter explores two mental representation constructs that may account for this vast variability.

2.4 INDIVIDUAL DIFFERENCES IN DISCOUNTING

So far, I have examined the history of intertemporal choice, from the normative discounting model *the discounted utility model* and the descriptive model *the hyperbolic discounting model*, the latter of which can account for a lot of observed anomalies to the former. However, the HDM and other *option-based* discounting models cannot account for all anomalies to the DUM, which many *attribute-based* models have sought to explain. However, there are still a series of contextual effects that these models do not account for either. Moreover, there is a wide range of heterogeneity in individuals' discount rates that remain unaccounted for (Carter, Meyer & Huettel, 2010; Figner et al., 2010; Loewenstein, Rick & Cohen, 2008), which will be the focus of this section.

To recap, an individual's intertemporal discount rate is the extent to which an individual discount the subjective value of a future reward as a function of the delay to receiving that reward. A person who is more likely to forgo a larger-later reward in favour of a smaller-sooner reward is said to have a high discount rate. High discount rates have real life correlates, as they are associated with younger age (Green, Fry & Myerson, 1994; Green, Myerson & Ostaszewski, 1999; Reimers et al., 2009), substance dependence (see Bickel & Marsch, 2001 for a review), obesity (Reimers et al., 2009; Weller et al., 2008), and lower levels of education and income (Reimers et al., 2009; de Wit et al., 2007). The aforementioned behavioural correlates imply that high discounting is to some extent related to other impulsive behaviours.

Both exponential and hyperbolic discounting models predict that an individual's discount rate should be unaffected by irrelevant contextual manipulations, and this is to some extent confirmed by correlational evidence. When measured five weeks apart, individuals' discount rates correlate between .66 and .75, showing a fairly stable discount rate (Kirby, 2009), and when measured one week apart, discount rates correlate between .70 and .73 (Matusiewicz et al., 2013). This is comparable to most personality measures, which are considered to be fairly stable within an individual across time.

There is a wide heterogeneity in discount rates, and demographic variables can only account for a small portion of this (Carter, Meyer & Huettel, 2010; Figner et al., 2010; Loewenstein, Rick & Cohen, 2008). Across individuals they can vary by over two orders of magnitude (e.g., Madden et al., 2004), and there have been many explanations offered to account for this variance. Above I listed some correlations to do with behaviours or socioeconomic factors, but differences in discount rates is also related to individual differences. For instance, de Wit and colleagues (2007) reported that preference for immediate rewards was related to intelligence, even when considering socioeconomic factors. They also found that higher discounting was related to impulsivity (see also Alessi & Petry, 2003). While others have argued that discounting is an adaptation to the individual's environment (Rogers, 1994; Haushofer & Fehr, 2014), these accounts suggest discount rate variability might be due to cognitive traits and abilities. This role of individual differences is a notion which forms much of the rationale for the first strand of research in this thesis.

The vast unexplained variability in discount rates may be accounted for by individual differences, but some individual differences may be due to the circumstances they live within. To revisit the view of discounting as a rational adaptation to the environment, Haushofer and Fehr argued people in unstable environments may focus more on the immediate future and ignore long-term benefits (Haushofer & Fehr, 2014). Specifically, they argue that poverty causes stress and negative emotions, and that this negative state lead to myopic decisions that are more beneficial in the short term than in the long run. When people in poverty have to direct their attention to meeting short-term goals, this happens at the expense of long-term goals. Equally, unstable environments make smaller-sooner choices more normative, because the larger-later option may disappear before the decision maker gets it.

Sometimes making a smaller-sooner choice is a more viable choice for low-income individuals. To borrow an example from Terry Pratchett's Men at Arms (1993), an individual may be choosing between a really good pair of leather boots for $50 that is going to last them ten years, or an affordable pair of cardboard boots for $10 that would last for two seasons tops. The choice might seem obvious, as the good but expensive shoes for $50 will last for 10 years, but the affordable boots for $10 will have to be re-purchased every year for 10 years, amounting to $100. However, if an individual has a monthly pay-check of $38 the choice will inevitably have to be the affordable boots that will cost them more in the long run. In a similar way, although people on lower incomes might particularly benefit from the extra income associated with a larger-later choice, they may find themselves in a situation where they simply need money immediately to survive. Thus, while the great unexplained variability in discount rates may be due to individual differences, they may also be due to the environment the individual exists within. Or, this variability may be due to what mental representations people generate when making intertemporal choices.

There has been limited research on the mental representations and processes underlying intertemporal choice. Mental representations refer to how the external world is symbolised in the mind, whereas mental processes refer to what the mind does with these mental representations. While research on the aforementioned option-based models (DUM and hyperbolic) and attribute-based models (IDM, tradeoff model, DRIFT and ITCH) is mostly concerned with fitting models to intertemporal choice data, they do carry assumptions about how people mentally represent and process these choices. Option-based models assume people compare options holistically by evaluating the subjective value of each option, given its delay, and then choosing the most attractive option. Meanwhile, attribute-based models assume comparisons are made between each attribute (time and outcome), such as the tradeoff-model that argues people trade off the differences in delays with the difference in amounts of money (Scholten & Read, 2010). Moreover, there is evidence that how people mentally represent the future can influence their intertemporal choice. This will be discussed in more detail in the next chapter. Thus, the great unexplained individual differences in discount rates may be due to how people mentally represent the future, and how they mentally process these representations.

2.5 LITERATURE SUMMARY

To summarise the literature, intertemporal choice concerns any decisions made in the presence that affect outcomes in the future, and delay discounting is specifically about *how* delay affects valuation of outcomes. When people discount, they forego a greater but delayed outcome over a sooner but smaller outcome, and someone who does this more often is said to have a high discount rate. The history of delay discounting research goes back to the 18th century, at least, but has gradually involved fewer psychological factors towards the 20th century. The discounted utility model (Samuelson, 1937) condensed discounting down to a single exponential discount rate factor that assumes individuals discount in a manner that is consistent across time. The model gained great popularity due to its algorithmic simplicity and became the benchmark model for normative intertemporal choice in the field of economics.

Normative discounting refers to how people *should* discount outcomes with time, but behavioural data from the field of heuristics and biases research in the area of judgement and decision making have offered more descriptive accounts. People appear to discount hyperbolically, which has led to the development of descriptive discounting models, such as the HDM (Loewenstein & Prelec, 1992). Both exponential discounting (e.g., DUM) and hyperbolic discounting (e.g., HDM) describe how people weigh amounts by delays for each option and then choose the option with the highest discounted value. However, hyperbolic discounting can account for inconsistent time preference, as there is more discounting for the near future and less discounting for the distant future.

Although the idea that people discount hyperbolically has gained a descriptive status of intertemporal choice, the emerging consensus amongst JDM researchers is that preference is construed when making judgement and decisions (Payne, Bettman & Johnson, 1992). Hyperbolic discounting, like exponential discounting, assumes that people should have internal stable discount rates, but there are anomalies of the DUM that cannot be accounted for by hyperbolic discounting. Thus, further models have been developed that aim to account for some of these anomalies. Thus, over the past decades there has been a rapid progression from traditional economic normative models of discounting towards increasingly more psychologically descriptive accounts to better account for behavioural data.

Models of intertemporal choice are either option-based or attribute-based (Payne, Bettman & Johnson, 1988), or somewhere in between (e.g., the interval discounting model by Scholten & Read, 2010). Option-based discounting models, such as the DUM and the HDM, describe how options are considered in isolation, weighing out comes by delays, and choosing the option with the greatest discounted value. However, more recent attribute-based models describe how options are compared directly across each attribute variable, comparing the differences in delays and the differences in values, and choosing based on which option has the best ratio between the two. Examples of attribute-based models include the tradeoff model (Scholten & Read, 2010), the DRIFT model (Read, Frederick & Scholten, 2013) and the ITCH model (Marzilli Ericson et al., 2015). These models represent a further shift towards a psychological descriptive account of discounting.

However, despite all of the above attempts at accounting for intertemporal choice in terms of fitting choice data to discounting models, there is still a vast amount of unexplained individual difference variability in discount rates (Carter, Meyer & Huettel, 2010; Figner et al., 2010; Loewenstein, Rick & Cohen, 2008). Although high discount rates correlate with a lot of demographic and socio-economic variables, and has been suggested as an adaptation to unstable environments (Rogers, 1994; Haushofer & Fehr, 2014), it may come down to more psychological factors. As will be discussed in the next chapter, various ways of mentally representing the future have been found to influence discounting, and the following chapter explores the role of mental processing in intertemporal choice. It could be that individual differences in discounting come down to how people mentally represent the future or how they mentally process these mental representations (e.g., option- and attribute-based comparison strategies).

2.6 CONTRIBUTION OF THESIS

The focus in recent years in delay discounting research has been on models explaining how people process or reason with the values they experience in intertemporal choice. Much of the legacy of economic theories has been to model how people *should* make intertemporal choices, whereas more recent psychological models have followed up with models that aim to describe how people *do* make intertemporal choices. However, finding which model best prescribe or describe intertemporal choice does little to *explain* how intertemporal choices are made on a psychological level. There is still very little known about what underlying processes and mental representations people employ when making intertemporal choices. From the more recent psychological literature it is clear that what matters are not the objective values, but the way in which they are represented in the mind of the decision maker.

As outlined in this literature review, the growing consensus amongst JDM researchers is that preference is constructed, and subject to context effects and biases (Payne, Bettman & Johnson, 1992). This marks a shift away from the legacy of economics that assumes people look up values on psycho-economic functions, following a series of logical axioms. In this thesis, I wish to take this direction further by examining what goes on in the mind of the decision maker. Specifically, my aim is to explore how people mentally represent intertemporal choice. For example, a decision maker may represent the intertemporal choice between a smaller-sooner and a larger-later monetary options in purely numerical terms, or as their subjective values, or in terms of how they would spend the monetary outcomes, or when they would receive them. Perhaps people rely on different mental representations in different circumstances.

As will be covered in detail in the next chapter, there is ample research which demonstrate that time has a great qualitative effect on how outcomes are mentally represented, and that decision makers differ in the way in which they represent aspects of their own personal future. For example, the research on *Construal Level Theory* show that the way in which people construe the near and distant future differs qualitatively, and that this in turn influences whether people discount more or less (Malkoc & Zauberman, 2006; Malkoc, Zauberman & Bettman, 2010; Kim, Schnall & White, 2013). There is also evidence from the memory literature on episodic future thinking, where the extent to which people think about their own personal future in a mentally experiential manner can also influence the extent to which they discount (Peters & Büchel, 2010; Benoit, Gilbert & Burgess, 2011; Cheng, Shein & Chiou, 2012; Liu et al., 2013; Lin & Epstein, 2014). Finally, people discount less when the delays are written as specific dates (e.g., "10 December 2020) rather than conventional delays (e.g., "in 4 months"; Read et al., 2005).

The change of discount rate as a result of different construal levels, episodic future thinking and the date/delay suggest that people can form different types of mental representations, and that these in turn increase or decrease discounting. Hence, some of the great unexplained variability in individual's discount rates might at least in part be related to variability, not just in time preference, but in mental representation of future outcomes. Thus, the heterogeneity of discount rates from person to person may be in part due to different people representing the future differently.

The great unexplained variability in discount rates may also be due to the comparisons people make, as per option-based and attribute-based discounting models. These comparisons may reflect mental processes, which in turn result from different mental representations; whether people represent options holistically in a manner that integrates their attributes (delay and outcome), or whether people represent these choices in terms of their attributes and the differences between them. Perhaps there are individual differences to whether people do option-based or attribute-based comparisons, or perhaps there are circumstantial reasons as to whether people do one or the other. In sum, when answering the question of whether some people discount more than others, I want to explore whether this is due to mental representations and the manner in which these are mentally processed.

Representations that may be more or less vivid and concrete, and more or less integrated, and influence whether people process them one way or another.

Moreover, there are some similarities across the variables that have been found to attenuate discounting: construal level, episodic future thinking and the calendar-date format of the date/delay effect. This will all be discussed in greater detail in the following chapter, but in short: I wish to explore whether presenting decision makers with delays written in a calendar date format prompts them to envision the time of receiving the delayed good in an episodic manner. This makes sense, as both calendar dates and episodic tags attenuate discounting (Peters & Büchel, 2010; Read et al., 2005). Moreover, there are similarities between the different construal levels for the near and distant future (Liberman & Trope, 1998; Trope & Liberman, 2003) and how episodic future thoughts are said to change with greater distance from the presence (D'argembeau and Van der Linden, 2004). Thus, it is possible that these are all various approaches, in the various research fields of psychology, attempting to measure the same underlying variable of representing the future. At the very least these might be a set of correlated variables that are all affected by similar representational effects.

To summarise, this thesis will explore the following:

- Whether individual differences in discounting can be explained by individual differences in episodic future thinking and construal levels (Chapter 3, Studies 1-3).
- Whether individual differences in construal levels are related to greater representation richness in episodic future thinking (Chapter 3, Studies 1-3).
- Whether the episodic-tagging effect and the date/delay-effect are related; do they have additive effects or are there no added effects of one when employing the other? (Chapter 3, Study 3)
- Whether the episodic tagging is truly an effect of episodic thinking or if it is simply drawing attention to whatever option has an episodic tag (Chapter 3, Study 3).
- Whether people make more attribute-based or option-based comparisons in intertemporal choice (Chapter 4, Studies 4-5).

- Whether individual differences in option-based versus attribute-based comparisons can predict individual differences in discount rates (Chapter 4, Studies 4-5).
- Whether individual differences in fixation durations and fixation transitions can predict individual differences in discount rates (Chapter 4, Studies 4-5).
- Whether the date/delay-effect or the episodic tagging-effect lead to a shift from attribute-based to option-based comparison strategies (Chapter 4, Studies 4-5).

3 MENTAL REPRESENTATIONS OF THE FUTURE

Any decision involving time requires some kind of representation of the future outcome. This section will discuss the research around mental representations of the future. There are numerous ways an individual could think about what might happen in the future. Szpunar, Spreng and Schachter (2014) developed a taxonomy of *prospection* that describes four different forms of future thinking: When people *predict* the future they attempt to estimate the likelihood of a future outcome, whereas when they *plan* they organise steps deemed necessary to achieve a goal, and when they make an *intention* it is the setting of such a goal. Finally, there is *simulation*; the act of constructing a specific mental representation of the future. It is the latter form of future thinking that will be the focus of this chapter.

So far, this thesis has focused on the quantitative representation of value over time. However, mental representations of the future are often much richer, and various areas of psychology have grappled with the way in which we represent anticipated future events. Recall the *anticipatory utility view* that had branched out from the first psychological theory of intertemporal choice, discussed in section 2.1. While still quantitative in nature, it was a shift towards a more qualitative approach that emphasised the importance of prospection. This view explained variability in time preference in terms of individuals' ability to mentally represent the future. Within contemporary cognitive psychology, there are two broad and largely unrelated areas that address how we mentally represent the future that bot have relevance for discounting. The first, from memory research, is *Episodic future thinking*, and the second from judgement and decision making is *Construal level theory*.

3.1 EPISODIC FUTURE THINKING

While memory research is broadly focused on the various types of memories people have from the past, episodic future thinking is concerned with how people use the same processes and information to think about their personal future. The relevance of episodic future thought when people make intertemporal choices for their personal future has been researched extensively, especially in the recent decade. The following sections will cover this research along with a general background on the episodic future thinking literature.

3.1.1 EPISODIC MEMORY

The concept of episodic future thought fit in to the taxonomy of memory. Memory is what allow people to store encode, store and retrieve information from the past over time, to influence future behaviour. Within memory a distinction is usually made between sensory processing, short-term (working) memory and long-term memory. Long-term memory can in turn be split into non-declarative (implicit) and declarative (explicit) memory (Graf & Schacter, 1985). Declarative memory is often what people think of when talking about memory, as these are the memories and the things we know that we are able to consciously recollect and put into words.

Tulving (1972, 1985) distinguished between two types of declarative memories: *semantic* and *episodic memory*, and defined the former as “knowledge of the world”, and the latter as memories of personally experienced events that enables mentally travelling back in time to re-experience these events (Tulving, 1985, 2001). Support for this claim comes from amnesic patients whose semantic memories are intact despite severe impairment in episodic memory (Korsakoff, 1889; Vargha-Khadem et al, 1997, 2001; Spiers, Maguire & Burgess, 2001).

Amongst 147 cases of amnesia related to hippocampal and fornix damage, *all* cases had impaired episodic memory, while many only had moderate semantic memory impairment (Spiers et al., 2001). Another study found that two patients who suffered hippocampal damage when they were too young to have developed semantic memory still showed normal development in speech, literacy and factual knowledge (Vargha-Khadem et al., 1997, 2001).

Conversely, some patients show intact episodic memory and impaired semantic memory (Yasuda, Watanabe & Ono, 1997; Kapur, 1999). All these differences in impairment between semantic and episodic memory supports the double dissociation between the two.

Consistent with the aforementioned hippocampal damage in amnesic patients with episodic memory impairments, functional neuroimaging studies show that the left hippocampus show more activity during episodic encoding but not when retrieving semantic memories (Prince, Tsukiura & Cabeza, 2007). Conversely, there is more lateral temporal cortical activity during semantic memory retrieval but not during episodic encoding. Out of 26 neuroimaging studies, 25 show greater left prefrontal cortical activity during encoding episodic than semantic memories, and there is greater right prefrontal cortex activity when people retrieve episodic memories rather than semantic memories (Wheeler, Stuss & Tulving., 1997).

All the different patterns of brain activity during episodic and semantic memory encoding and retrieval suggest that these are two distinct memory processes. Episodic memory as a distinct memory process is important and relevant because of its relevance to episodic future thinking, as discussed in the following section.

3.1.2 MENTAL TIME TRAVEL

So far, I have outlined the specific type of declarative memory called ‘episodic memory’ that is about remembering the personal past. This form of memory allows people to *mentally time travel*, by not only mentally reconstructing past events but also about *constructing* the potential personal future. This ability to project oneself into the personal past and future is an aspect of the broader *autonoetic consciousness*, which enables an individual’s self-awareness of their own identity and existence in their subjective past, present and future (Tulving, 1985, 2001). So, while semantic memory enables us to retrieve the name of the street we grew up in, it is episodic memory that enables the re-experience of personally experienced events that took place on that street.

While the episodic memory component of autonoetic consciousness allows one to mentally travel back in time, *episodic future thinking* allows for mental time travel to the future. Specifically, e*pisodic future thinking* (EFT)is an individual's capacity to imagine their personal potential future events, enabling them to anticipate and simulate these events (Atance & O'Neill, 2001; Schacter, Addis & Buckner, 2008; Szpunar, 2010). EFT research is often concerned with comparing future representations in other animals, as well as the research areas of prospection, simulation and projection (Szpunar, 2010; Szpunar, Spreng, & Schachter, 2014). Episodic future thoughts, like episodic memories, are often contextualised in time, space and emotional valence. Similar to how episodic memory allows us to re-experience an individual's personal past, EFT allows them to pre-experience their personal future. Just like *knowledge* of the past and *remembering* the past is different, so is *knowing* about the future and mentally *projecting* oneself into that future.

Neuropsychological research on patients with brain injury supports the distinction between knowledge and remembering that applies both to episodic memory and episodic future thinking (Klein, Loftus & Kihlstrom, 2002; Levine et al., 1998; Stuss, 1991; Tulving, 1985). These studies described patients who retained semantic *knowledge* about the past and the future, but were unable to remember their personal past events or *project* themselves into personal future events. For instance, Klein and colleagues (2002) described amnesia patient DB who showed severe episodic memory impairment while still demonstrating knowledge of his *non-personal past* such as historical events. He was equally impaired in his ability to imagine his personal future while still demonstrating the same ability to anticipate future non-personal public events as neurologically healthy age-matched controls. That is he could remember the *known* past but not his *lived* past, and could imagine the *known* future but not the *lived* future. Thus, it appears that the distinctions made between episodic and semantic memories of the past also applies to the distinction between episodic and semantic future thoughts.

The emergence of episodic future thought and episodic memory appear to be the same in childhood development, somewhere between the ages of 3 to 4 years (Atance and Meltzoff, 2005, Atance and O'Neill, 2001, Atance and O'Neill, 2005, Busby and Suddendorf, 2005, Suddendorf and Busby, 2005). The simultaneous emergence of the two lends support to the argument that they are related, and possibly two aspects of the same system, such as Tulving's autonoetic consciousness.

The idea that the ability to remember the personal past is related to the ability to imagine the personal future is also supported by neuroimaging studies that have found considerable overlap in the areas of increased brain-activity when people recall past events and imagine future events (Okuda et al., 2003; Szpunar, Watson & McDermott 2007; Addis, Wong & Schacter, 2007; Buckner & Carroll, 2007). For instance, two functional neuroimaging studies both found that the brain areas implicated in remembering the personal past are the same as those involved in simulation and imagination of personal future events (Addis, Wong & Schacter, 2007; Szpunar, Watson & McDermott, 2007). Bot studies were very similar in that participants were given word cues to think of and imagine specific personal events, but I will describe Addis et al. (2007) in detail as this method informed a series of studies in this thesis.

In each trial, a noun cue was presented to participants for 20 seconds, and they were told to imagine a personal past or future event for a specific time interval (1 week, 1 year, 5-20 years). Once they had come up with a specific event, they pressed a button and used what was left of the 20 seconds to give details on the event. Moreover, phenomenological qualities (detail, emotionality, personal significance etc) of the events were measured using self-report rating scales, based on those by D'Argembeau and Van der Linden (2004; to be described later). Both Addis et al (2007) and Szpunar et al (2007) found a striking similarity in brain activity while participants imagined the personal past or future, as compared to non-episodic control tasks, and the phenomenology of past personal events matched many of those of future personal events.

This neural and phenomenological overlap, along with case studies of amnesic patients, strongly suggest that episodic future thinking and episodic memory share a common mechanism and are part of the same core network. This "core" network, better known as *the default network*, includes the medial temporal and frontal lobes, posterior cingulate and retrosplenial cortex, a lateral parietal and temporal areas of the cortex (Schacter et al., 2007; 2012). These findings led to the development of the *constructive episodic simulation hypothesis* (Schacter & Addis, 2007) which will be discussed in the following section. To summarise, while episodic memory is often thought to be about remembering the past, it also allows us to "remember" the future, by using the same mental mechanisms and neurological network to mentally represent what the likely future events will be like.

3.1.3 CONSTRUCTIVE MEMORY

The *constructive episodic simulation hypothesis* (Schacter & Addis, 2007) is the idea that episodic future thinking enables us to think about the future by means of drawing upon past experiences in order to construct novel representations of potential personal future events. This is the same constructive mechanism that can lead to erroneous recall resulting from incorrectly combining various elements from memories of past experiences. For instance, an individual who is highly adaptive at flexibly combining episodic memory elements may mistakenly recall the cashier they met in the morning as being the perpetrator behind a street robbery later that day (see Carpenter & Schacter, 2017). Essentially, the adaptive ability to flexibly recombine features from past experiences in order to mentally simulate novel future events is sufficiently advantageous that it outweighs the cost in erroneous recall that can result in incorrectly combining features.

Numerous studies have examined the specific ways EFT can be advantageous to intertemporal choice, emotional regulation, subjective well-being, empathy and pro-social behaviour. The following section will discuss these areas in turn, except for intertemporal choice that will be explored in detail in section 3.1.4.

3.1.3.1 USAGE OF EFT IN COGNITION

EFT has been discussed and examined in various areas of cognitive and social psychology. For example, it appears to aid in emotional regulation, as suggested by the reduced EFT specificity and vividness of individuals with heightened anxiety (MacLeod, 2016; Miloyan, Bulley & Suddendorf, 2016; Wu et al., 2015). Individuals encouraged to engage in EFT (by administering an *episodic specificity induction*, see Madore, Gaesser & Schacter, 2014) and later made to simulate conceivable solutions to their worrying future events were better at emotion regulation than controls. They made more constructive behaviours to address the event that worried them, were better at re-evaluating the event and showed better subjective well-being (Jing, Madore & Schacter, 2016).

Other research providing evidence for how EFT can enhance subjective well-being comes from a study in which participants were asked to simulate the details and emotions related to an ongoing stressful event. Compared to controls, they later reported employing more beneficial coping mechanisms (Taylor et al., 1998). Other evidence comes from a study in which first-time pregnant women mentally simulated going into labour and arriving at the hospital in time. The more detailed and coherent their simulations, the more likely they were to predict a positive outcome and the less worried they were about the labour (Brown et al., 2002). Research has also shown how EFT can increase empathy and prosocial behaviour. When presented with depictions of a person struggling, engaging in EFT of helping the person increased prosocial intentions to aid an individual presently in need of help (Gaesser & Schacter, 2014; see also Gaesser, Dodds & Schacter, 2017). Overall, EFT appears to have ample advantages for emotional well-being and prosocial behaviour.

3.1.3.2 EFT PHENOMENOLOGY

At the start of this chapter, *prospection* was defined as an umbrella term for all the ways people can think about the future, be it predicting, planning, intending or simulating. When simulating the future (or the past), people *self-project* into that mental simulation. S*elf-projection* is often used in the literature to refer to how people shift their perception from the presence to mentally simulate their personal potential future, in reference to themselves. This idea fits well with Tulving's autonoetic consciousness where people see the self as an extension into the personal past and the personal future, and mentally time travelling to the personal future or past come with certain experiences that have specific phenomenological qualities too them.

D'argembeau and Van der Linden (2004) have explored the phenomenological characteristics of mental time travel. They asked participants to re-experience or pre-experience events that differed in temporal distance to the presence and then to rate these events on various phenomenological 7-point scales such as 'visual details', 'sounds', 'clarity of location' etc. They found that temporally distant events, both past and future, had less contextual and sensory detail than temporally near events. This again supports the idea that episodic memory and EFT relies on the same underlying mechanism.

They also found that emotional intensity increased with delay, and that people felt more positive emotions towards temporally distant events. Importance of self-image decreased with delay into the past, but for the future it remained the same for the near and distant future. This was the only measure that did not change with delay. However, similar self-rated measures by Berntsen and Bohn (2010) decreased with delay. They found that importance of self-image and relevance to life story and identity increased with delay. Thus it appears that events imagined for the distant future are more important to the self.

In a subsequent study, D'argembeau and Van der Linden (2006) also asked participants to remember past events and imagine likely personal future events. Following this participants wrote a brief description of the event and rated it on a series of 7-point phenomenological rating scales, adapted from the Memory Characteristics Questionnaire (Johnson et al., 1988) and the Autobiographical Memory Questionnaire (Rubin et al., 2003). The scales assessed the representations for things like temporal information, intensity, valence, personal importance, visual details and many others (see Table 1 in D'argembeau and Van der Linden, 2006). Participants were also assessed for their capacity for generating visual imagery (VVIQ by Marks, 1973). Those with greater capacity for visual imagery reported experiencing more visual and other sensory details for imagining future events as well as remembering past events.

In sum, the findings by D'Argembeau and Van der Linden (2004; 2006) supports the notion that EFT and episodic memory are part of the same underlying mechanism, as both show the same phenomenological characteristics, depending on the temporal distance from the present into the past or the future (D'Argembeau & Van der Linden, 2004). Moreover, individual differences in the capacity for generating visual imagery greatly influence these phenomenological experiences (D'Argembeau & Van der Linden, 2006). The following chapter outlines ways EFT attenuates discounting. It is possible that the individual differences in EFT phenomenology can explain the unexplained variability in individual discounting differences.

Overall, the constructive and adaptive nature of episodic memory (Schacter, Norman & Koutstaal, 1998) has led to the idea that a functional role of episodic memory is to envision the personal future (Schacter & Addis, 2007; Hassabis & Maguire, 2007; Suddendorf & Corballis, 2007, Tulving 1985), or more specifically, to draw upon memories of past experiences in order to make decisions for the future, as suggested by Boyer (2008). More relevant for this thesis, however, is the relationship between EFT and discounting. Boyer (2008) hypothesised that the ability to envision a delayed reward enables people to pre-experience its affective impact. Consequentially, people value the delayed reward more, thus attenuating its discounting. This will be described further in the following section.

3.1.4 RELEVANCE TO DELAY DISCOUNTING

Most EFT research has concerned itself with which memory processes are involved and what the memory representations are like phenomenologically. But researchers have also investigated how EFT pertains to decision making involving time. Recall the argument above that episodic memory, or at least EFT, serves to let us envision our personal future. It therefore makes sense that EFT would be involved in the decisions we make for future outcomes, and so intertemporal decision-making research and EFT research converge in this area when looking at the influence of EFT when making intertemporal decisions.

To recap chapter 2.2, although discount rates are treated as relatively stable traits, they can be affected by many contextual variables and other variables. These include but are not limited to explicit zero effects (Magen et al., 2008), option skew (Stewart et al., 2014), effects of emotions (Li, 2008; Van den Bergh, deWitte & Warlop, 2008; Kim & Zauberman, 2013; Lerner et al., 2013; Guan et al., 2015; Wilson & Daly, 2017), subadditivity (Read, 2001) and superadditivity (Scholten & Read, 2004). Another contextual factor that affects discounting is EFT, which is the focus of this sub-chapter. The aforementioned context effects generally influence how people *evaluate* the values quantitatively. While this may be the case for the effect of EFT upon discounting as well, EFT might fundamentally change how the options are mentally represented in a more qualitative way.

As noted before, not only do people discount more than they should according to economic theory but this discount rate varies greatly from person to person (Carter, Meyer & Huettel, 2010; Figner et al., 2010; Loewenstein, Rick & Cohen, 2008), and this individual difference variability is largely unexplained. The research literature on discounting often centres around temporal myopia; the idea that the future is less clear than the present, or at the very least less salient. Discounting is often discussed in terms of the qualitative differences in the representation of the immediate and delayed rewards, yet most theories of discounting only refer to the quantitative change in value with delay. I argue that understanding the representation rather than just the valuation of outcomes over delays allows a more precise understanding of intertemporal choice, and perhaps a better understanding of the as yet largely unexplained individual differences in discounting.

One way in which EFT can influence discounting is by interfering with the emotions around the immediate option. Boyer (2008) theorised in a review paper how mental time travel can serve as an “emotional break”, in which the emotions experienced from episodic future thinking interferes with and counteracts the tendency to engage in short-sighted ‘myopic’ decision making. This view is remarkably similar to *the anticipatory utility view* described in chapter 2.1, where people prefer rewards sooner than later, but being able to anticipate future rewards allow us to delay gratification (W. Jevons, 1888; H. Jevons 1905).

The performance of patients with amnesia in decision making tasks sheds light on whether advantageous decision making require conscious knowledge of choices made in the individual's past. Gutbrod and colleagues (2006) tested whether explicit memory (declarative conscious long-term memory) is required to make advantageous decisions in a gambling task. The Iowa gambling task draw cards from four decks of cards, some of which lead to gains and some lead to losses. After a few trials healthy control participants learn which decks lead to more or less gains and losses, based on their previous choice of decks to draw from. While healthy controls tended to prefer advantageous choices, amnesic participants performed at chance. This suggests that the ability to explicitly remember the reinforcements to make advantageous choices is necessary in order to form a choice preference. Without the ability to mentally time travel, people are more susceptible to make appealing but ultimately self-defeating choices because they have no explicit memories of the negative or positive outcomes of past choices.

Considering the date/delay effect in the context of Boyer's (2008) argument that the capacity to envision delayed rewards allows us to pre-experience their impact on our emotions, it could be that people value the delayed reward more when the date-format make them engage in EFT which allows them to have this pre-experience. And in turn, pre-experiencing the later delay makes them pre-experience the emotions of receiving the reward at that later time and thus attenuate discounting.

3.1.4.1 EFT INFLUENCING DISCOUNTING.

The idea that pre-experiencing the later delay in a discounting task can attenuate discounting has been demonstrated more directly by Peters and Büchel (2010). They asked 30 participants to make a list of their personal future plans, and rate these events on 6-point scales for arousal, valence and personal relevance. The researchers selected 7 events per participants, and matched these on their ratings as well as giving each event an *episodic tag*; a verbal label of the event that would be used in the subsequent discounting task. Before this task, participants' discount rates for an immediate value of 20€ was estimated.

In the subsequent discounting task, which was carried out the next day, 2 sessions of 118 trials each presented each participant with a larger-later reward based on their individual discount rate (ranging from 20.50-80€). Participants were to choose between this larger-later option and an immediate sum of 20€. In half of these trials, the larger-later option was accompanied by one of the episodic tags generated for that participant. This tag reminded the participant of what they would be doing at the point in time when the larger-later reward would be received. The other half of the trials were used as controls and used 7 delays that were distinct from those in the episodic tagging trials. Thus, both conditions displayed the amount and time, but in only one did participant see episodic tags. Finally, participants indicated on 6-point scales the frequency of associations evoked by each episodic tag, and how vivid these associations were. This was averaged across events to an *imagery score* for each participant. They also wrote down their feelings and thoughts about each tag.

Results showed significantly lower discounting when larger-later options were tagged than when they were not tagged. This episodic tagging effect suggest that being reminded of your own personal future plans leads to less impulsive decision making. Moreover, the size of the tag effect correlated positively with greater imagery scores, suggesting that the tag effect was greater when EFTs were more vivid.

In a similar study (Benoit, Gilbert & Burgess, 2011), participants were handed a written scenario accompanied by a monetary amount and a time of receipt (e.g., "£35 in 180 days at a pub") and asked students to *imagine* spending that sum of money at that time and place. Other participants were given the same scenario, but their task was to *estimate* what they could buy with the money there. Following either task, participants were then to choose between that time and money combination and £25 now. The ones who had imagined spending the money in the future were more likely to choose that larger-later option than those who simply made an estimate of what it was worth. In other words, like the study by Peters and Büchel (2010), engaging in EFT reduced discounting.

Cheng, Shein and Chiou (2012) explored whether prospection priming would make people delay gratifications. Participants who were primed with prospection by being asked to imagine what their everyday life circumstances might be like 4 years from now would discount less in a subsequent delay discounting task than those asked to imagine present day life circumstances. While the researchers did not reference EFT per se, they linked prospection to the literature on *episodic memory* (Tulving, 1983), *prospective memory* (Brandimonte, Einstein & McDaniel, 1996) and *autonoetic awareness* (Tulving, 2004), when conceptualising *prospection*. Thus, the findings of this study supports the notion that EFT attenuates discounting.

Liu and colleagues (2013) manipulated the emotional valence of EFT to explore its role in reducing discounting. They found that, compared to not imagining any events, imagining positive future events led to less discounting and imagining negative future events led to more discounting. Moreover, they found that imagining neutral future events had the same effect on discounting as imagining no event at all. While EFT influence delay discounting, the direction this takes appears to be determined by emotional valence, as it determines the extent EFT leads to higher or lower rates of discounting.

Lin and Epstein (2014) also explored the role of the emotional valence of episodic thinking on delay discounting. While completing conventional delay discounting tasks, participants would either visualise neutral or positive personal future events. The attenuating effect of EFT upon delay discounting was moderated by individual's working memory capacity. That is, individuals with high working memory capacity showed less delay discounting when engaging in EFT than those with less working memory capacity. Contrary to Liu and colleagues (2013), this study showed a similar effect of positive and neutral EFTs on discounting. While those with high working memory capacity discounted less when engaging in EFT, this effect was attenuated when the EFTs were positive. High working memory capacity was only advantageous when EFTs were neutral. Despite the contradictions to Liu et al. (2013), the study supports the idea while engaging in EFT influences intertemporal choice, the direction this takes depends on emotional valence.

EFT can also have effects on everyday behaviour, like food intake. The ability to delay gratification has been linked to obesity in the literature (Davis et al., 2010; Francis & Susman, 2009; Reimers et al., 2009 Weller et al., 2008), and it logically follows that a tendency to choose an immediate reward (food) over a long-term good (health) would be linked to greater risk of obesity. Daniel, Stanton and Epstein (2013a) adapted the Peters and Büchel paradigm (2010) by asking obese participants to think of specific future events before completing discounting tasks with delays corresponding to those events. They were also played audio recordings of themselves describing these episodic future events while partaking in a food related task designed to trigger impulsive eating of energy-dense food. They found that EFT reduced both delay discounting as well as food intake in these obese individuals. In a follow-up study (2013b) they found that the extent to which EFT reduced discount rates were the same for lean and overweight/obese individuals. EFT appears therefore equally effective in reducing impulsive behaviour across these weight groups.

There is also some correlational research to support the idea that individual differences in discounting and EFT are related in adolescence (Bromberg, Wiehler & Peters, 2015). Participants' discount rates were estimated by having to make a series of choices between €10 immediately and amounts ranging from €10.50- €227 and delays from 1 to 180 days, until the algorithm could determine their indifference point. To estimate participants' EFT, participants were given an autobiographical memory interview in which they described personal past and future events that were then transcribed and rated by someone not part of the data collection. Results showed that more vivid episodic imagery was negatively associated with discounting behaviour. If these results generalise to the general adult population, as will be explored in the present research, then individual differences in EFT might account for some of the unexplained variability in discounting.

3.1.4.2 DISCOUNTING AND THE FUTURE SELF

Tangibly related to EFT, is Hershfield and colleagues' research on how people's sense of psychological connection to their future selves. Based on the wider literature that highlights how essential this is in intertemporal choice (Ainslie, 1975; Elster, 1977; Parfit, 1971, 1987; Schelling, 1984; Strotz, 1955; Thaler & Shefrin, 1981) the authors explored how this psychological connectedness varies with the different ages of the "selves" in one's personal future (Parfit; 1971). A 40-year-old individual is likely to feel more connected to their 45 year-old self than to their 70 year-old self, as the latter is a more distant self. And in the absence of this connection, the distant future self may feel like a completely different person to oneself. Hence, Hershfield and colleagues (2011) made participants feel more connected with their future selves, in order to make them save more for their future, by digitally ageing portrait photos of the participants.

They argued that while people may have the capacity of visualising their future selves, they may not spontaneously do so, and if they do it may not be visual, definite and specific. For the 'future self' condition, the aged portraits were presented to participants in an immersive virtual reality environment when they looked into a virtual mirror. However, in the 'current self' condition saw non-aged portraits of themselves instead. Following this, the researchers asked participants to imagine receiving $1000 and whether they would put it into a checking account, spend it on an extravagant occasion, buy something for someone special or invest in a retirement fund. Participants in the 'future self' condition saved more than twice as much for their retirement fund. Because retirement saving is effectively about allocating money to the future instead of the present, this is effectively a discounting task. Thus, by envisioning themselves as they will look in the future, they discounted less. Although not a direct exploration of EFT, this finding aligns well with the above studies on how EFT can reduce discounting.

While Hershfield et al. (2011) never make the connection explicit, the idea of psychological connectedness with future selves fits with Tulving's (1985, 2001) idea of autonoetic consciousness. This is the idea that mental time travel allows us to see ourselves as extended through to our personal past and future, and Hershfield's findings support this notion by demonstrating how increasing psychological connectedness with the future self makes people make more advantageous decisions for the future self. This also fits with Boyer's (2008) idea of EFT serving as an emotional break, as it allows us to pre-experience the emotions of future outcomes. Hershfield and colleagues reference Lowenstein, O'Donoghue and Rabin (2003) who propose that presently experienced emotions are stronger than those the person expects to feel in the future. Consequentially, people place more weight on their present emotions, the emotions of the present self, rather than the emotions of the future self.

Another study by Hershfield et al. (Ersner-Hershfield, Wimmer & Knutson, 2009) used neuroimaging to explore whether people are connected to their future selves and what this does for intertemporal choice. While scanned with event-related fMRI, participants made judgements about which trait adjectives fit their present self, their future self, a present other or a future other. In the following week, participants did a series of discounting tasks to estimate the individual participant's discount rate. Results showed similar neural activation pattern (in the rostral anterior cingulate cortex) for when people think about their self as when they think about a present or future other, suggesting that people by default think of their future selves as they do with strangers. Moreover, participants who had the greatest neural activation difference between when they thought about their present and future self, discounted more than those who appeared to think similarly of their present and future self.

These findings suggest that people who see their present and future selves continuously, make more advantageous decisions for the future. By Tulving's (1985, 2001) autonoetic consciousness account, the ability to and extent to which people project themselves into the future by mental time travel, can reduce discounting. Specifically, this study demonstrates how there are individual differences in the extent to which people do this and how this affects discounting. Thus, individual differences in autonoetic consciousness may explain some of the large unexplained individual variability in discount rates.

3.1.4.3 EFT IS NOT NECESSARY FOR DISCOUNTING.

What the aforementioned studies suggest is that when people think episodically about their personal future it makes them place more importance on it However, EFT is not a requirement for choosing delayed options over immediate ones in decision making tasks (Kwan et al., 2012). Patient KC had hippocampal damage and thus no episodic memory or ability to imagine personal future events (Craver et al., 2014; Rosenbaum et al. 2005). Patient KC completed a series of delay discounting tasks (as per Green & Myerson, 2004), in which he chose between hypothetical smaller-immediate and larger-later monetary rewards. The immediate amount started off as half of the delayed reward (e.g., $50 now vs. $100 in 1 week) and was then adjusted up (or down) in the next trial if he chose the delayed (immediate) option in the preceding trial, ultimately leading to a discount rate for KC for each of the delayed rewards ($100 and $2000). KC completed the same procedure 6 times in the span of 1 month, without any explicit recall of having done the task before.

Results showed that KC's discount rate was within the range of the healthy control participants. By discounting smaller amounts more than he did larger amounts, he also showed a *magnitude effect* (see chapter 2.1.3.1), which is a common finding in the discounting literature. And he was as consistent as the control participants in his discounting for all the 6 sessions he was tested. Thus, despite his episodic amnesia as a result of his extensive hippocampal damage, patient KC demonstrated that he valued future rewards without being able to mentally time travel and engage in episodic future thinking.

These results contradict the Boyer's (2008) idea that being able to mentally pre-experience personal future events is essential in order to make intertemporal choices. When patient KC was interviewed about his choices after completing the task, he simply described a "blank" state of mind when asked to imagine how he would use the future rewards. However, when he was asked about what strategy he used in the discounting tasks, he said he chose "the best deal" based on his gut feeling. Meanwhile the control participants said they relied on both episodic and non-episodic strategies. Combined with the findings in the previous section that engaging in EFT can reduce discounting, this suggests that although engaging in EFT may reduce discounting, it is not required for normal performance on a discounting task.

Based on the findings that patient KC discounted normally despite his episodic amnesia (Kwa et al., 2012) and that EFT reduces discounting (Peters & Büchel 2010; Benoit et al., 2011), Palombo, Keane and Verfaellie (2015) wanted to explore whether the attenuating effect of EFT on discounting was absent in amnesic patients. The patients in the study had various forms of medial temporal lobe damage related amnesia that impaired their episodic thinking. Both the amnesic patients and healthy patients underwent a task modified from that of Peters and Büchel (2010) and Benoit, Gilbert and Burgess (2011).

Consistent with previous findings, both the amnesic patients and controls showed normal discounting. However, only the controls reduced their discounting when engaging in EFT. The amnesic patients discounted to the same degree as they had been doing in the conventional non-EFT delay discounting condition. This supports the notion that while making intertemporal choices does not require EFT, engaging in EFT reduces discounting. Although whether an individual who had never been capable of EFT would show typical discount rates has yet to be researched.

In sum, autonoetic consciousness is an individual's ability to mentally time travel into their personal past and future. Episodic memory is the more widely researched ability to imagine past personal experiences, and the more recently defined episodic future thinking is when people imagine their personal future experiences. Thus the argument that episodic thinking exists for people to draw upon experiences of their past to envision, plan and make decisions for their future. In support of this, many advantages of EFT have been discovered, such as for intertemporal choice, as numerous studies show how engaging in EFT can lead to making more advantageous choices for the future relative to the presence. However, studies on amnesic patients show that EFT is not necessary to make intertemporal choices.

3.2 CONSTRUAL LEVEL THEORY

The previous section gave an overview of the research on episodic future thinking, which has direct implications for how future outcomes may be represented. Similarly, this section will cover another, largely non-overlapping area of research that is also focused on representations of the future: Construal level theory. Whereas EFT has originated from the memory research literature, Construal level (Liberman & Trope, 1998; Trope & Liberman, 2003) hails from the research area of judgement and decision making.

3.2.1 LITERATURE

Construal level theory describes how increased *psychological distance* (be it spatial, temporal or social distance) makes an event mentally construed in with greater abstractness. Specific to time, it describes how mental representations of the future differ *qualitatively* depending on the relevant event's temporal distance from the presence. Distant-future events are represented as *high-level construals*, conveying goals, meaning, and purpose, in an abstract, decontextualized and organised fashion. Conversely, near-future events are represented as *low-level construals* which revolve around practicalities, feasibility and procedural aspects of an action in a way that is more concrete, contextualised and detailed. The relevance this has for JDM research is that judgements and decisions for temporally distant events are based on high-level construals, whereas those for temporally proximate events are based on low-level construals.

Early evidence for this difference came originally from Liberman and Trope (1998, study 1) who presented participants with a series of written activities (watching TV, taking an exam, reading a sci-fi book), occurring either the following day or the following year. Participants were to write a short description of these events which researchers either classified as either low-level or high-level construals. The researchers found that an activity, such as "moving into a new apartment", was more often described in a low-level construal manner when it took place the following day. For instance, people would describe it as "packing and carrying boxes". However, when the very same activity was to occur the following year, it was more often described in a high-level construal manner, with descriptions like "starting a new life". Thus distant-future activities were more focused on superordinate goals (high-level construals) and near-future activities were described in terms of subordinate goals (low-level construals).

In the second part of the same study, Liberman and Trope (1998, study 2) had participants choose which out of two pre-made descriptions (adapted from Vallacher & Weger's "Levels of Personal Agency", 1989) they felt best described a given activity for 19 activities in total. These would describe "why" someone would do it (high-level construal) or "how" it would be done (low-level construal). For instance, for the activity "studying", participants could choose between the descriptions: "do well in school" (why; high-level construal) or "reading a textbook" (how; low-level construal). The results were consistent with the previous findings, with more low-level 'how' construals chosen for near-future activities and high-level 'why' construals chosen for distant future activities.

A subtle distinction between EFT and temporal construal is that EFT is based on a *quantitative* decline in representation richness with an increase in time from the near to the distant. In contrast, temporal construal is about the *qualitative* difference between the how the near and distant future is mentally represented. Depending on this temporal proximity, some features become more or less important. When the near future is mentally represented as a low-level construal, more detailed, procedural, contextual and peripheral features are granted greater importance in judgement and decision making. Whereas when the distant future is mentally represented as a high-level construal, more abstract, central, goal and purpose-oriented features are important. For instance, someone who might book an early morning flight for a distant future holiday to save money (more important in a high-level construal), but would be willing to spend more money on a near future holiday if it meant they would not have to wake up so early (more important in a low-level construal).

Construal level theory predicts that for goal-directed activities, people care more about the desirability of that goal for high-level construals, but are more concerned with the feasibility of attaining that goal for low-level construals. Liberman and Trope (1998) tested this prediction by asking students, in a real-life scenario, to choose between an "interesting but difficult" (higher in desirability) and "easy but boring" assignment (higher in feasibility). More students chose the more desirable option for distant future-assignment, and the more feasible option for near-future assignments, demonstrating how construal levels make us weight option features differently.

This is just a brief overview of the general principles of low-level and high-level temporal construal. However, several studies have explored the relationship between temporal construal and delay discounting. This will be discussed in the next section, after detailing some of the problems with construal level theory, as well as similarities between temporal construal and EFT.

3.2.1.1 PROBLEMS WITH CONSTRUAL LEVEL THEORY

One problem with Construal Level Theory is that, due to broadly specified high- and low-level construals, it can generate predictions that point in opposite directions, making the theory difficult to falsify as it would essentially be supported no matter the outcome. This has proven particularly challenging in intertemporal choices concerning morality. To reiterate, the theory describes how people are more concerned with more abstract high-level construals for temporally distant events, and more concerned with more concrete low-level construals for temporally proximate events. Morality is a more abstract concept and something people are more concerned with when making decisions for the more distant future, whereas pragmatism a more concrete concept that people are more concerned with for the more proximate future. Thus, the theory predicts that morality (high-level construal) should matter more in temporally distant events, whereas people are more pragmatic (low-level construal) for temporally proximate events (Eyal & Liberman, 2012).

Eyal, Liberman and Trope (2008) explored this prediction by presenting Israeli participants with descriptions of moral transgressions: sibling incest, eating a deceased family pet, cleaning the floor with the nation's flag, marital cheating and exam cheating. Those who were told the hypothetical events were to happen next year rated the actions as more wrong than those told it would happen tomorrow, suggesting they had greater moral concerns for the high-level construed temporally distant event. In support of this, Agerstöm and Björklund (2009) found that Swedish participants judged distant-future moral transgressions were judged more harshly and led to more anger than near-future moral transgressions.

When attempting to replicate the findings of Eyal et al. (2008) when using the same methods, Gong and Medin's (2012) findings were in the opposite directions. Their American participants rated the wrongness of *near-future* moral transgressions higher than that of *distant-future* moral transgressions. In other studies, they directly manipulated construal levels, and still found that participants were more morally outraged for low-level construals than high-level construals, contrary to the predictions of construal level theory and the findings of Eyal et al. (2008), translated the study materials of Gong and Medins (2012) into Hebrew, and their participants were either more morally outraged when moral transgressions were presented as low-level construals rather than high-level construals, or there was little effect of construal level on moral judgements at all (Gong & Medin, 2012; see also Žeželj & Jokić, 2014).

These diverging findings present a problem for construal level theory. On one hand, *morality* as an abstract concept is a *high-level construal* and so should be of greater concern for distant-future events. But on the other hand, near-future events are more concrete and tangible. This makes moral transgressions construed in a low-level manner easier to imagine, making it easier to mentally simulate, and thus people are more readily repulsed by them. From this, it appears as though construal level theory has the potential of making mutually exclusive predictions when it comes to morality. While people may be more morally repulsed by eating a deceased family pet for the distant future, they are also more repulsed by it as the near future is more easily imaginable.

Overall, Construal Level Theory appears poorly specified in some areas, such as morality, to the extent that it allows for making entirely opposite predictions. This makes the theory hard to falsify when it can account for either outcome. Immoral behaviours are abhorrent in the distant future because we are more concerned with more abstract high-level construals then, and equally immoral behaviours are abhorrent in the near future because then we are more concerned with more concrete low-level construals that make things mor tangible and vivid. So, caution is advised when making post hoc construal level accounts for observed behaviours. With that being said, these potential problems with the theory are unlikely to impact on the present research, as none of the studies specifically look at morality. Rather, the focus will be on the more general actions where the theory seem to make unambiguous predictions: low-level construals focus on *how* to do something, and high-level construals on *why* one would do something.

3.2.1.2 SIMILARITIES BETWEEN CONSTRUAL LEVELS AND EFT

Construal Level Theory and Episodic Future Thinking are largely discussed separately in the literature (some exceptions include: Yi et al., 2016; Nan & Quin, 2019). A simple Google Scholar search for “episodic future thinking”+”construal level” resulted in only 181 results, as of December 2020. Temporal construal is usually discussed in the judgement and decision making literature and EFT in the memory literature, though it has been given increasing attention in the JDM literature. Regardless, construal levels and EFT have in common that they describe how near-future events are mentally construed with more sensory and contextual detail.

Studies on EFT phenomenology show that episodic future representations have fewer sensory and contextual detail the further away from the present they are (D’Argembeau, & Van der Linden, 2004). Specifically, sensory details (visual details, sounds, smell/taste), location (clarity, clarity of spatial arrangement of objects and people), time of day and feelings of re-experiencing the event *decreased* with delay. This fits well with low-level construals, which are construed for the near future; the construals are more detailed (like sensory details), contextualised (like location and time of day) and vivid (like feelings of re-experiencing the event). Thus, it appears that EFT and construal level theory make similar predictions for how people mentally represent the near future.

Meanwhile, emotional valence and intensity of emotions *increased* with delay. That is, people felt things more strongly and more positively with delay. This fits with the idea of high-level construals for the distant future, as these construals are more focused on desirability and goals. So similar to how EFT and construal level theory make similar predictions for the near future, they also appear to make similar predictions for the distant future. Moreover, Berntsen and Bohn (2010) found that events imagined for the distant future were more important to the self. In sum, temporally near events are pre-experienced more vividly and temporally distant events of greater personal significance, (D'Argembeau & Van der Linden, 2004; Berntsen & Bohn, 2010), resembling the constructs of low- and high-level construals, respectively.

Construal level theory is not only similar to Episodic future thinking in the way it describes our mental representations about the near and distant future (Atance & O'Neill, 2001). Construal levels, much like EFT, can influence intertemporal choice (Malkoc & Zauberman, 2006; Malkoc, Zauberman & Bettman, 2010; Kim, Schnall & White, 2013; see also Mischel, Shoda & Rodriguez, 1989). This will be discussed further I the next section.

3.2.2 RELEVANCE TO DELAY DISCOUNTING

So far, I have discussed the general principles of construal level theory along with supporting along with studies that highlight some of the problems with the theory. Like EFT, construal level theory describes how we think about the near and distant future differently, but the two constructs are also similar in that they influence to what extent we make impulsive choices in delay discounting tasks. Much like how making people engage in EFT for the distant future makes people more likely to wait for a larger-later reward, changing how people construe the near and distant future can influence discounting as well.

3.2.2.1 LOW-LEVEL CONSTRUALS INCREASING DISCOUNTING

However, there is far less research done on the effect of construal level upon discounting behaviour than there is on the effect of EFT upon discounting behaviour. While Malkoc and Zauberman (2006) primarily focused on demonstrating how discount rates decline more over time when people delay rather than when they expedite the time of receipt, they also found that this effect was moderated by different levels of concreteness. Before looking at construal level they found that participants showed greater discount rates for a 3-day interval than for a 10-day interval, and participants discounted more when delaying than when expediting the time of receipt. They also found an interaction effect between intervals and temporal framing (expediting vs deferring), in which the decline in discounting with greater delays was more pronounced when delaying receipt than when expediting it.

To explore how construal levels affected the above choice behaviours, participants were asked to imagine purchasing and watching a DVD in great detail, whereas controls were not asked to do this visualisation task. Participants who did the visualisation task showed no difference in discounting between deferring and expediting. In the control condition, self-reports revealed that delay frames led to more concrete representations whereas expedite frames led to greater abstraction. So, when the visualisation made participants think in a more concrete manner, the two frames were both mentally represented at the same construal levels. Consequentially, discounting patterns were the same when expediting as well as when delaying the time of receipt.

The authors argued that the delay- and the expedite-frames are inherently construed at different levels. When people delay the receipt, their mental representation of consumption is more concrete, detailed and vivid, because this was a more near-future event before delaying, making it a high-level construal. Whereas when they expedite receipt, it is less detailed and vivid and more abstract, because the initial time of receipt was temporally further away, making it a high-level construal. When visualising, the two time frames were construed at the same levels, and so people discounted more when expediting as this was now construed at a low level.

In sum, the delay frame was already construed in a low-level concrete manner, whereas the visualisation procedure made the previously abstract expedite frame also construed in a low-level concrete manner, thus eliminating the difference in discounting between the delay and the expedite frame. However, the finding that visualisation *reduced* discounting in the delay frame complicate matters. As noted above, there is *greater* discounting over time in the delay frame because it is inherently construed at a more concrete low construal level. But, in the case of greater visualisation leading to *less* discounting over time the delay frame, this suggest that low-level construals *decrease* discounting. The authors explained this post hoc, based on participants' self-report, that the low-level construals made participants who were delaying more concerned with scheduling when to watch the DVD, as feasibility is another low-level construal factor. Again, there is the danger of construal level theory being able to explain any findings post hoc due to poorly specified construal levels.

Overall, this demonstrates both how construal levels are inherent to the decision process in delay discounting tasks, but also how manipulating these construals can influence discounting behaviour. Differences in discounting can be eliminated when construal levels are made to be the same, suggesting that construal levels at least contribute to discounting behaviour.

3.2.2.2 HIGH-LEVEL CONSTRUALS DECREASING DISCOUNTING

In the aforementioned study, the experimenters demonstrated how making representations of the future more concrete, and thus on a low-level construal, led to more discounting. In a subsequent study, Malkoc, Zauberman and Bettman (2010) demonstrated how high-level construals made people discount less, and show a smaller decline in discount rates over a time interval, compared to low-level construals. Participants were first asked to imagine buying a camera. The *alignable* condition chose between two digital cameras with comparable differences (e.g., 4 hour battery life vs. 6 hour battery life) whereas the *non-*

alignable condition chose between a digital and a traditional camera with incomparable differences (e.g., 4 hour battery life vs. 2 frames shutter speed). Then participants described in detail the pros and cons of each camera. Second, participants decided whether to delay the delivery of the camera from same-day delivery to 3 or 10 days.

The non-alignable differences would, as confirmed in a pre-test, lead to more abstract mindset, in other words high-level construal. In the pre-test, participants did the above alignability manipulation, as well as Liberman and Trope's (1998) task in which people describe an action (e.g., "studying") as either high-level (e.g., "do well in school") or low-level construal (e.g., "reading a textbook"). Participants who evaluated non-alignable items classified more actions as high-level construals, indicating that comparing items on incomparable attributes prompted a more abstract, high-level construal, mindset.

The results showed that, as before, participants discounted more for more immediate than more distant intervals, as their willingness to pay more to avoid a delivery delay was greater for the 3-day than the 10-day interval. Crucially, this time horizon manipulation interacted with alignability. Participants who imagined buying a camera in the non-alignable condition discounted less than those in the alignable condition. That is, the non-alignable condition induced a more abstract, high-level construal, thinking that moderated the decline in discounting for longer time intervals. In short, high-level construal mindsets reduced discounting. A control condition in which participants *only* made shipping time decisions showed the same discounting behaviour as the alignable condition, suggesting that this more concrete mindset is the default mindset when discounting.

In another experiment of this study, the authors predicted that the date/delay effect would moderate the interaction between construal and interval so that the interaction would be stronger when delays were presented as days than when they are presented as dates. The date format makes people more focused the event of the outcome rather than the time they have to wait and so they discount less (Read et al., 2005). Malkoc and colleagues contrasted this with the more conventional delay format, which lead to a more concrete representation that makes people discount more.

The researchers had participants imagine choosing a retirement plan. The alignable condition compared two options on the same 7 attributes, and the non-alignable condition compared the two options on 7 different attributes. Following this, participants were told that the plan chosen made them eligible for a $200 bonus paid immediately. However, due to great demand they were offered to delay the receipt and participants indicated what the smallest amount they would demand for this delay. The delay would be either 3 months or 1 year, and the delay format either in calendar dates or number of months.

The results showed a main effect of time horizon, as participants discounted more for 3 months than 1 year, and a main effect of delay format, as participants discounted more for delays than dates. The same interaction effect as the previous study was also demonstrated, where comparing different attributes in the non-alignable condition led to less discounting than when comparing the same attributes in the alignable condition. However, this interaction effect was absent for the date format. When the delays were presented in a date-format, comparing the same or different attributes led to similar discount rates.

The previous experiment showed how people think more abstractly when they cannot as easily rely on the immediate context, such as when the camera attributes were difficult to compare, and that this shift in processing style led to reduce discounting. The authors argued that because of this, a discount task that is framed so that people rely less on the immediate context, then the resulting abstract thinking style should lead to reduced discounting. Analogous to how non-alignable (as opposed to alignable) camera attributes are difficult to compare, date formats (as opposed to delay formats) are difficult to compare. The resulting high construal-level abstract thinking style leads to lower discount rates.

3.2.2.3 LOW-LEVEL CONSTRUALS DECREASING DISCOUNTING

The above two studies have demonstrated how more concrete low-level construals lead to greater discounting, and more abstract high-level construals reduces discounting. Similar to

Malkoc and Zauberman (2006), Kim, Schnall and White (2013) focused on how the *difference* in construal levels for the two choice options lead to discounting. They argued that the construal level differences between each option lead to greater discounting as the more immediate option is construed more concretely and the delayed option is construed more abstractly. When one option is construed at a low-level and the other at a high-level, this makes them difficult to compare directly, and so people prefer the smaller-sooner option. And if the two options can be compared more directly, people should prefer the larger-later option. This, according to the researchers, should be possible to achieve by not only having both options construed at a low level, but also when both options are construed at a high level.

To demonstrate how having both options construed at a low-level could reduce discounting, they manipulated construal levels by having participants choose between Paris trip vouchers where one option was superior in price and hotel star rating (e.g., a £300 voucher for a 3 star hotel now vs. a £500 voucher for a 5 star hotel in one year), making both options concrete low-level construals. Compared to controls who chose between checks of the same value (e.g., £300 now vs. £500 in 1 year), those presented with concrete choices discounted less. Thus, the researchers demonstrated how having both options construed on a low-level reduces discounting.

In the same study, Kim and colleagues (2013) investigated how high-level construals also can reduce discounting when both options are construed in such a manner. Construal level does not only apply to the temporal dimension, but also to social dimensions. Closer social relations are construed in more low levels, whereas distant social relations are given more high-level construals (Trope & Liberman, 2003). So, in order to make both options construed on a high level, participants made intertemporal choices for acquaintances rather than for themselves. This manipulation also made people discount less. Both these studies encouraged both options to be construed at the same level, and as both manipulations resulted in less discounting. The researcher demonstrated how manipulating construal levels of either the sooner or later option could be used to reduce discounting, whether that is making both options construed at a high level or at a low level.

One critique of the latter study is that it might not be construal level differences that lead to attenuated discounting when people make decisions on behalf of acquaintances. Rather, research on self-other decision making show that people take greater risks in decisions made for others than for themselves (Beisswanger, Stone, Hupp, & Allgaier, 2003; Fernandez-Duque & Wifall, 2007; Pollai & Kirchler, 2012; Stone & Allgaier, 2008; Stone, Yates, & Caruthers, 2002; Wray & Stone, 2005). So, in the same vein as people show less loss-aversion in decisions involving risk, they might also show less impulsivity in decisions involving time. Hence, participants might have been more willing to forgo the smaller-sooner in favour of the larger-later, not just because of temporal construal level differences, but for the many reasons specific to the self-other difference found in the decision making research literature (Polman, 2012).

The aforementioned findings that construal levels affect discounting suggest that one way in which representations of future outcomes may affect discounting is that delayed outcomes might be construed differently than that of immediate outcomes. This makes people choose the smaller-sooner option as it is construed at a lower level. However, it is not entirely clear why this pattern of construal would lead to higher levels of discounting. The argument is generally that more concrete representations lead to attenuated discounting, but the reasons why are not made explicit. It is not given that a concrete contextualised £100 is more attractive to the decision maker than an abstract goal-related £100. The Malkoc et al (2006; 2010) studies point to the concreteness and contextualised nature of low-level construals as a factor that make people choose an option. However, it is not entirely clear why the abstraction of items makes them less desirable, as desirability in and of itself is a high-level construal. It appears that the contextualised and concrete aspects of construal levels are the more important ones here.

3.2.2.4 CONSTRUAL LEVELS AS INHERENT TO DISCOUNTING

The studies on discounting and construal levels discussed so far have all made claims about construal levels being an inherent part of discounting. Without any contextual manipulation, the smaller-sooner option is construed at a low level and the larger-later option at a high level. Liberman and Trope (2003) have argued that if construal levels were to explain discounting behaviour, it would be closer to an *attribute based* account (such as the interval discounting model or the tradeoff model) than an *option based* one like hyperbolic discounting. The theory would place amounts as a high-level construal and delay as a low-level construal because amounts represent a *central* feature (a high-level construal) and delay a *peripheral* feature (a low-level construal). This would make people choose with amounts in mind when making choices for the distant future, and with the delay in mind when the options are in the near future. This is consistent with preference reversals in the delay discounting literature (see the common difference effect in section 2.1.3.1; Loewenstein & Prelec, 1992).

This theoretical account together with the studies by Malkoc et al. (2006; 2010) and Kim et al. provide a strong argument for construal levels as an inherent part of delay discounting, where the default is a low-level construed smaller-sooner option and a high-level construed larger-later option. While this accounts for *why* people are more inclined to choose more low-level construed options, the similarities between EFT and construal levels might provide an account for *how*. The argument from the EFT literature is that being able to mentally time travel made people more able to experience the vividness and detail of one's personal future, and research shows how doing this in a discounting task reduces discounting (Peters & Büchel, 2010; Benoit et al., 2011). So, it could be the vividness and detail of a contextualised and concrete low-level construal that make people choose this option.

Despite the phenomenological similarities between EFT and construal levels, and their similar effects on intertemporal choice, they are generally discussed separately. EFT is usually covered in the memory research literature, whereas construal level theory is linked to judgement and decision making research. EFT tends to *quantitatively* describe how increasing delay leads to a decrease in the number of details contained in the episodic future representation. Conversely, construal level theory describes how the high-level construal of a distant-future event is *qualitatively* different from the low-level construal of a near-future event. The two conceptualisations of how we mentally represent the future may be describing the same thing: that with increasing delay, it is increasingly hard to imagine the details of a representation, with only the more enduring goal-directed representations remaining for longer delays.

This section has outlined construal level theory and the ways it relates to delay discounting and EFT. A series of studies support the notion that construal levels are an inherent part of discounting. Given the great unexplained variability in discounting (outlined in chapter 2), and the observation that construal levels, and sometimes EFT, are part of discounting, the great individual differences in discounting might at least in part be due to individual differences in construal levels and EFT.

3.3 STUDY 1

3.3.1 RATIONALE

As discussed in chapter 2.3, there is a wide heterogeneity in individuals' discount rates (Madden et al., 2004) for which most of the variance remains unexplained. From the EFT literature we can see that people discount less when they engage in EFT (Peters & Büchel, 2010; Benoit, Gilbert & Burgess, 2011), and low-level construal levels can also attenuate discounting (Kim et al., 2013). Moreover, the low-level construals and episodic future thoughts people have for near-future events have more sensory and contextual detail (D'Argembeau & Van der Linden, 2004; Liberman & Trope, 1998). The similarities between these two constructs might mean that they share mental representations and that people's spontaneous propensity to construe delayed outcomes in a particular way may predict the extent to which they discount outcomes that have a similar delay.

Thus, it is possible that the richness and amount of detail in an individual's representations of their personal future affects their discounting. So perhaps individual differences in the manner and extent to which people represent their own personal future can account for some of the unexplained variability in discounting. In other words, those who discount less might also be those who have more EFT richness and detail and more low-level construals.

The studies outlined in this chapter aims to examine whether delay discounting, EFT and CLT are all related. Each of the three constructs were measured using conventional standard measures in order to examine how each measure vary with delay, as well as how an individual's score on each measure may correlate. If any of the constructs are related, one would expect them to correlate, and to be affected by delay in a similar manner:

The 3 key predictions all concern the relationship between the 3 constructs:

- H1a: Discounting correlates negatively with EFT richness.
- H1b: Discounting correlates positively with high-level construal preference.
- H1c: EFT richness correlates negatively with high-level construal preference.

First, given the literature showing how EFT varies across the population, and that EFT reduces discounting, one would expect to see a negative relationship between discounting and self-reported EFT representation richness. Less discounting would be associated with more EFT representation richness (H1a).

Second, if construal and EFT are based on the same mental representations of the future, one would expect to see a correlation between people's construal of the future and self-reported measures of EFT representations. Specifically, more EFT representation richness should be negatively correlated with high-level construal preferences (H1c).Finally, if construal and EFT share mental representations, discounting should decrease with increased low-level construals the same way that discounting should decrease with increased EFT representation richness (h1b).

Study 1 examines the relationship between discounting, EFT and construal levels, with the use of standard measure conventionally used for each of the three constructs. The study was web-based, testing a large and diverse participation pool.

The standard measures produce 5 predictions from the relevant research literature. Replicating these findings would support the reliability of the data:

- H2a: Increased delay will decrease valuation.
- H2b: Increased delay will increase high-level construals.
- H2c-j-: Increased delay will decrease autonoetic consciousness (H2c), sensory detail (H2d), spatial context (H2e), temporal context (H2f), emotional experience (H2g) and representation richness (H2h); and increase emotional valence (H2i), personal importance (H2j), use of words (H2k) and coherent story (H2l).

3.3.2 METHODS

3.3.2.1 PARTICIPANTS

All 313 participants (median age: 33; 45% female) were US-based and recruited through Amazon Mechanical Turk. They were each paid $1.50 for completing the 15-minute study, which was executed in Adobe Flash (see Reimers and Stewart, 2015) and conducted on July 30-31, 2014. Two duplicate entries were removed from the initial participant count of 315.

3.3.2.2 DESIGN AND PROCEDURE

In addition to demographics questions, the study consisted of three tasks: one measuring construal level, one measuring discount rates and one measuring EFT phenomenology. The same four delays were used for all three measures within-subjects: 1 day, 1 week, 1 month and 1 year. Each of the three measures are described in the following sections.

3.3.2.2.1 Temporal construal

This study measured construal level preference by using the methods obtained from the aforementioned Liberman and Trope (1998) study, in which participants chose between a low-level and a high-level construal description of a study. A selection of the activities and associated descriptions from this study were used, originally obtained from Vallacher and Wegner (1989).

Participants were presented with a series of activities, that were each described in two ways, and participants were asked which description fit best. Low-level construal descriptions were written in terms of *how* the activity would be done, and high-level construals were about *why*. For instance, if the activity was “cleaning the house”, the description for low-level construal read “vacuuming the floor”, whereas the description for high-level construal read “showing one’s cleanliness”.

There were 12 such activities (i.e., trials) in total, presented in sets of 3, for 4 different delays: “a day’s time”, “a week’s time”, “a month’s time”, and “a year’s time”. The events were randomly allocated to delays for each participant, and the delays were presented in a random order. The left-right order of the two description options was also randomised.

A trial would begin with an activity and its delay displayed in a centre-screen box on their own for 2.5 seconds. Then the two options would appear below the activity, asking participants to click the option that best described the activity. Once they had clicked on their chosen option, a slider appeared where participants would indicate the strength of their preference. The slider ranged from “No real preference at all” to “Strongly preferred my choice”. Once preference had been indicated, a “next” button appeared, allowing participants to proceed to the next trial.

Each participant’s construal preference was determined by multiplying the slider position by 1 if they preferred a high-level construal, and -1 if they preferred a low-level construal. Because construal preferences varied across trials, construal score for each activity was standardised. For each question, the mean of the distribution of scores was set to 0, and the standard deviation to 1. For each participant, a mean construal preference was calculated for each of the four delays.

3.3.2.2.2 Delay discounting

Discount rates were measured based on participants’ choices in a series of conventional intertemporal choice tasks, choosing between a “smaller-sooner” and a “larger-later” option. More specifically, each trial consisted of a binary choice where each option had a monetary value and a delay. The smaller-sooner delay was immediate, and the amount was adjusted based on the participant’s response to the preceding trials. The larger-later amount was a fixed sum, and the delay was one of the following delays: 1 day, 1 week, 1 month or 1 year.

of binary choices were presented to participants, each option consisting of a monetary value and a delay. The smaller-sooner amount, which could be received immediately, was adjusted based on participants’ responses to preceding trials. The larger-later option was a fixed sum to be received at four different delays: in 1 day, 1 week, 1 month, or 1 year.

Each of the 4 delays started with a binary choice between a delayed sum of $100 and half of that instantly, i.e., $50 now. In the next trial, the immediate sum was adjusted up or down depending on the participant’s previous choice response. For instance, if the participant chose $50 over $100 in the first trial, they would be asked to choose between $25 now and $100 later in the next trial. However, if they chose $100 over $50 initially, the next trial would have them choose between $75 now and $100 later. There were 6 such binary choices per each of the 4 delays, making a total of 24 binary choice tasks. The order of the 4 delays were randomised.

This whole 24 trial procedure was repeated again, using a delayed sum of $5,000 instead of $100, making it 48 delay discounting trials in total.

3.3.2.2.3 Episodic future thinking

This final task measured EFT phenomenology by employing the phenomenological rating scales also used by D'Argembeau and Van Der Linden (2006). There were 4 trials, one for each delay (1 day, 1 week, 1 month, 1 year). In a given trial, participants were instructed to imagine a personal event likely to occur near that point in time, and visualise this event while an on-screen timer counted down from 30 seconds. Participants were then able to proceed to a text-box where they described the event in at least 50 characters.

Lastly, participants rated the mental representation of the just-imagined event on 13 phenomenological rating scales. These covered 9 distinct areas, of which 5 related to strength of detail: Autonoetic consciousness ("While imagining the event, I feel as though I am experiencing it.", "While imagining the event, I feel that I travel forward to the time when it would happen."), sensory representations ("My representation for this event involves visual details.", "My representation for this event involves sounds."), spatial context ("My representation for the location where the event takes place is [not at all clear / very clear]", "Relative spatial arrangement of objects in my representation for the event is: [not at all clear / very clear]", "Relative spatial arrangement of people in my representation for the event is:" : [not at all clear / very clear]"), temporal context ("My representation for the time of day when the event takes place is"), and emotional experience ("While imagining the event, I feel the emotions I would feel if the event occurred").

The remaining questions were for: emotional valence ("If this event happened, my emotions would be: [very negative / very positive]"), personal importance ("This event is important to me (it involves an important theme or episode in my life)"), use of words ("While imagining the event, it comes to me in words."), and coherent story ("While imagining the event, it comes to me as a coherent story and not as an isolated scene.").[2]

3.3.3 RESULTS

3.3.3.1 TEMPORAL CONSTRUAL

Temporal construal preference was measured for each of the four delays, and the effect of delay upon construal preference can be seen in Table 3.1 and Figure 3.1. There was a weak monotonic relationship between delay and high-level construal, $F(3, 936) = 2.53$, $p = .056$, $\eta_p^2 = .008$, failing to replicate and confirm the prediction that preference for high-level construals increase with delay (H2b), even though the data was rending in that direction. Consistency of construal preference appeared consistent across delays as preference ratings correlated between .60 and .67. The one-way repeated measures ANOVA was sufficiently powered ($n = 313$, $\alpha = .05$, $1 - \beta = 0.996$) to detect the small effect size according to the post-hoc power analysis[3].

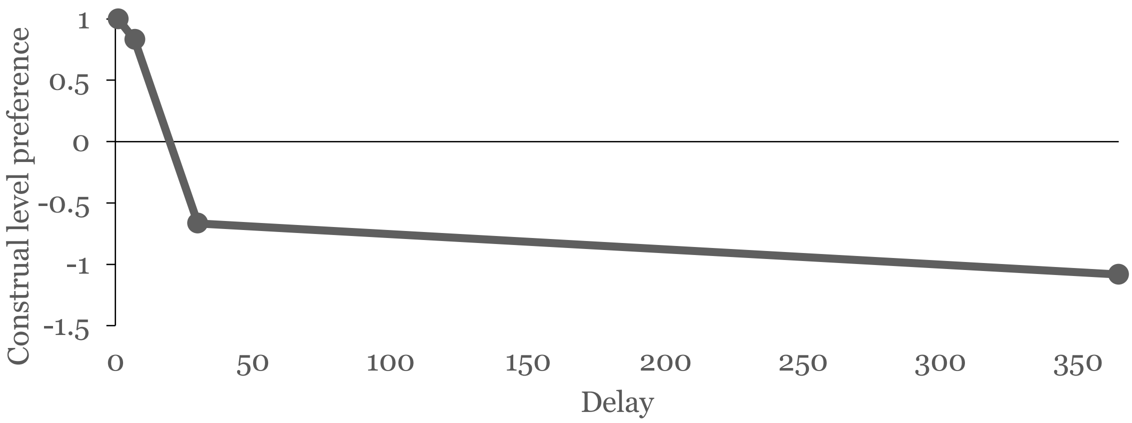
Table 3.1: Descriptive stats for construal level preference per delay.

	1 Day	1 Week	1 Month	1 Year
Mean	-.12	-.10	.08	.13
Standard deviation	2.32	2.29	2.21	2.26

Note. construal level preference means and standard deviations per delay. Positive values mean people on average chose more high-level construals, and negative values mean people on average chose more low-level construals.

[2] The measure 'visual perspective' was not included in this measure as it was too lengthy to include, given it required participants to read and comprehend a detailed paragraph before answering. 'Emotional intensity' was inadvertently left out.
[3] This and all the following post-hoc power-analyses in this thesis use G*Power (Faul et al., 2009).

Figure 3.1: Mean proportionate construal level preference across the four delays.



Note. Participants' average construal level preference (y-axis) with delay (x-axis), relative to the score on the day 1 delay. The more temporally distant from the presence, the more participants chose high-level construals over low-level construals, which a steep drop between 1 week and 1 month into the future. Note that this graph is for illustrative purposes only. The means have been transformed to show the change in construal levels over time. See Table 3.1 for the actual means and standard deviations.

3.3.3.2 DELAY DISCOUNTING

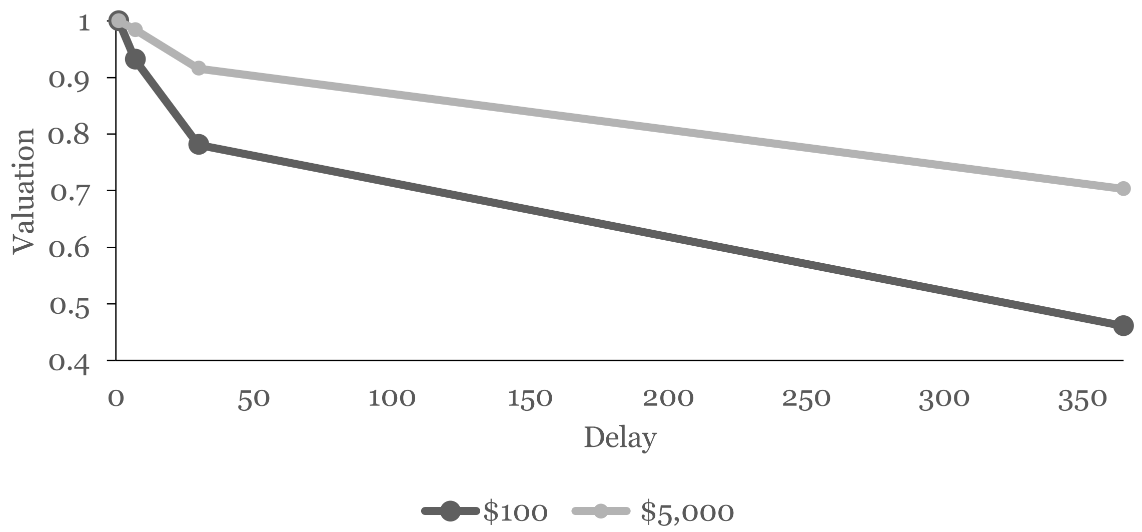
Participants' discount rates were measured for each of the four delays, and mean proportionate valuations of $5,000 and $100 in 1 day, 1 week, 1 month and 1 year can be seen in Table 3.2 and Figure 3.2. For instance, participants were indifferent to $43 immediately and $100 in 1 year, on average. There were only 8 participants who valued the delayed amount more in 1 year than in 1 day, and they only did this for one of the two delayed amounts. Therefore, no participants were excluded from the analysis for such inconsistent discounting. There was a clear effect of delay on valuation of both the $100 reward, $F(2.4, 756) = 497$, $p < .001$, $\eta_p^2 = .614$, and the $5,000 reward, $F(2.0, 630) = 169$, $p < .001$, $\eta_p^2 = .35$, confirming the predictions from the discounting literature (H2a). (Huynh Feldt corrections were applied to compensate for violations of sphericity throughout.) Participants valued the delayed reward significantly less with increasing delay to receipt. Post-hoc power analyses indicated both tests were well-powered ($n = 313$, $\alpha = .001$, $1 - \beta = 1$).

Table 3.2: Mean (st.dev) valuations for each delayed value per delay.

	1 day	1 week	1 month	1 year
$100	94.31 (13.76)	87.85 (18.21)	73.69 (24.77)	43.46 (29.79)
$5,000	4794.50 (685.19)	4719.34 (719.93)	4390.35 (1144.58)	3370.81 (1661.41)

Note. The mean (standard deviation) valuation for $100 and $5,000 across the four delays. For instance, valuing the delayed value of $100 in a year as $43.56 means that participants on average chose $43.56 instantly over waiting a year to receive $100.

Figure 3.2: Mean proportionate valuations across the four delays for both amounts.



Note. Participants' mean proportionate valuations for each delayed value and delay at 1 day, 1 week, 1 month and 1 year from the presence. With increased temporal distance from the presence, the more participants discounted delayed rewards.

Note that this graph is for illustrative purposes only. The means have been transformed to show the change in valuation over time. See Table 3.2 for the actual means and standard deviations for each of the delayed rewards.

For each of the two delayed rewards for every participant, a standard discounting function (V = A / (1+kD)) was fit to the 4 delays, and the best fit discount value (k) was identified. The median discount values were 0.006 $days^{-1}$ for the \$100 reward, and 0.0007 $days^{-1}$ for the \$5,000 reward. Because the discount rate distribution was skewed, log-transformed values of k were used for all the following analyses.

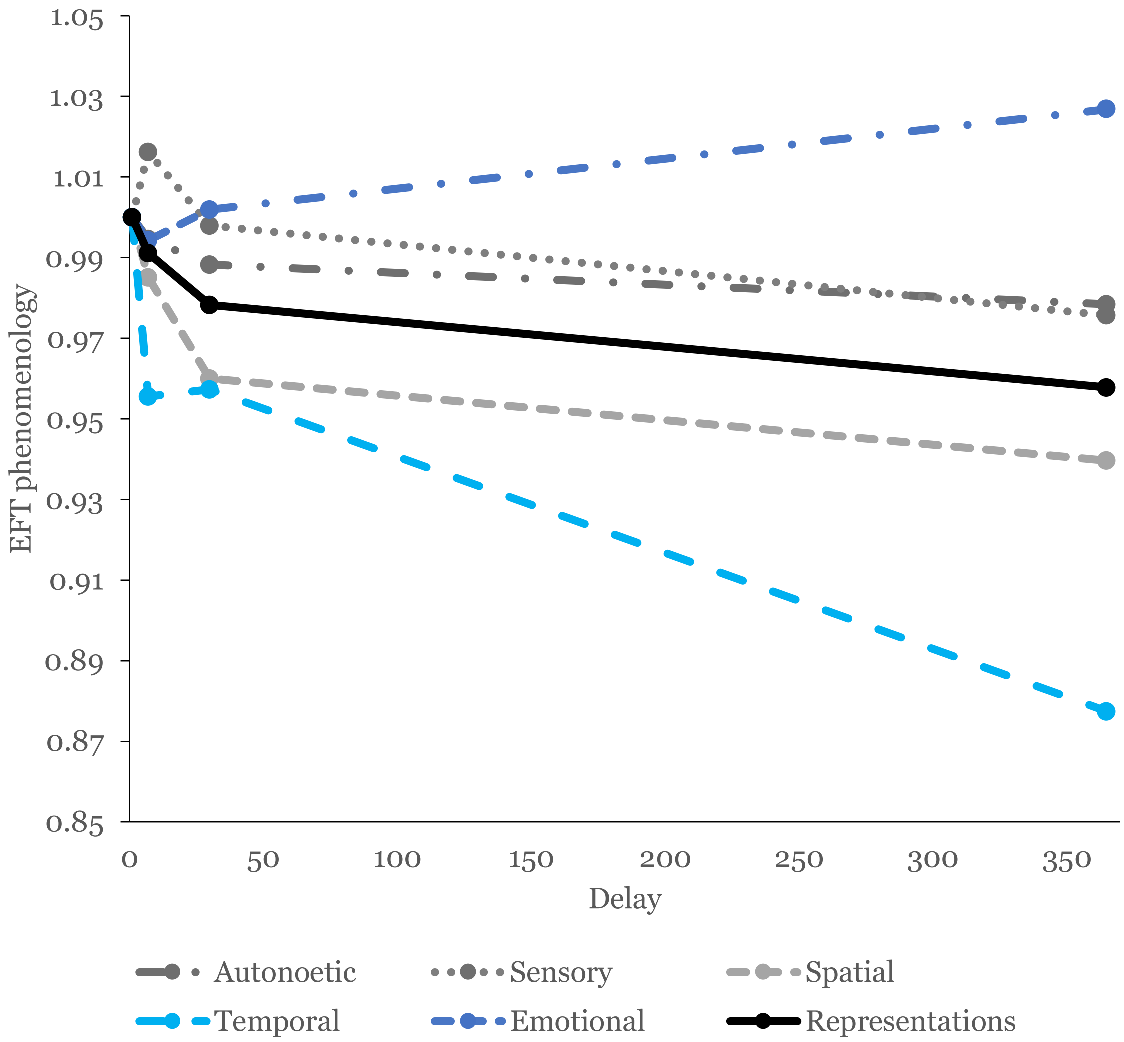
The overall findings replicated what is commonly found in delay discounting research. First, the effect of delay on valuation was consistent with hyperbolic discounting, as is a commonly found in delay discounting research: there was a rapid drop on valuation for shorter delays and this decline levelled out with longer delays. Second, there was a clear effect of magnitude (section 2.1.3), as there was a steeper discount rate for \$100 than there was for \$5,000, mean log(k\$100) = -5.27, mean log(k\$5,000) = -7.03, $t(312) = 17.5$, $p < .001$, $d = .99$). Lastly, the discount measurements within participants appear consistent, as the correlation between log(k\$100) and log(k\$5,000) was .70.

3.3.3.3 EPISODIC FUTURE THINKING

EFT phenomenology was measured across the delays: 1 day, 1 week, 1 month and 1 year. Table 3.3 and Figure 3.3 shows the effect of delay on self-report based measurements of EFT phenomenology. Amongst these measurements, only *spatial context*, $F(2.9, 916) = 8.77$, $p < .001$, $\eta_p^2 = .027$ (with Huynh Feldt corrections applied) and *temporal context*, $F(3, 936) = 14.51$, $p < .001$, $\eta_p^2 = .044$, declined significantly with delay. That is, EFT representations set further into the future had weaker spatial and temporal contexts. While *autonoetic consciousness, sensory representations*, and *emotional representations* declined in vividness with delay, this effect was not significant. However, consistent with the literature, the *emotional valence* $F(3, 936) = 6.81$, $p < .001$, $\eta_p^2 = .021$ and *personal importance* of the EFT increased with delay, $F(3, 936) = 26,9$, $p < .001$, $\eta_p^2 = .079$ but there was no effect of delay on use of words or coherent story. Each ANOVA above were well powered according to post-hoc power analysis (see Table 3.3).

Comparing the means of each phenomenological measure from 1 day to 1 year into the future, all variables that were predicted to increase (emotional valence, personal importance, use of words, coherent story) or decrease (autonoetic consciousness, sensory detail, spatial context, temporal context) with delay, did so. The only exception to this was *emotional experience*, which increased with delay, contrary to predictions.

Figure 3.3: The representation richness variable and the 5 individual variables.



Note. The 5 individual representation richness variables (autonoetic, sensory, spatial, temporal, and emotional) along with the representation richness composite variable, across all 4 delays (1 day, 1 week, 1 month, 1 year). All but the emotional variable decreased with increased delay.

Note that this graph is for illustrative purposes only. The means have been transformed to show the change in valuation over time. See Table 3.3 for the actual means and standard deviations for each of the phenomenological measures.

Table 3.3: EFT phenomenology for the two delays.

	1 Day	1 Week	1 Month	1 Year	*p*	η_p^2	1 - β
Autonoetic consciousness	11.13 (2.75)	11.07 (2.71)	11.00 (2.57)	10.89 (2.80)	.277	.004	.89
Sensory detail	9.87 (2.79)	10.03 (2.93)	9.85 (2.86)	9.63 (2.99)	.133	.006	.90
Spatial context*	**16.73** (3.82)	**16.48** (3.84)	**16.06** (3.83)	**15.72** (4.09)	**.000**	**.027**	**1**
Temporal context*	**5.63** (1.68)	**5.38** (1.79)	**5.39** (1.73)	**4.94** (1.92)	**.000**	**.044**	**1**
Emotional experience	5.23 (1.60)	5.20 (1.51)	5.24 (1.49)	5.37 (1.46)	.195	.005	.86
Emotional valence*	**5.40** (1.46)	**5.52** (1.57)	**5.57** (1.53)	**5.83** (1.43)	**.000**	**.021**	**1**
Personal importance*	**4.20** (1.93)	**5.31** (1.92)	**4.72** (1.82)	**5.12** (1.82)	**.000**	**.079**	**1**
Use of words	4.27 (1.88)	4.35 (1.87)	4.32 (1.86)	4.41 (1.83)	.466	.003	.83
Coherent story	4.62 (1.78)	4.70 (1.79)	4.67 (1.77)	4.79 (1.80)	.322	.004	.82
Representations*	**48.59** (9.94)	**48.16** (10.08)	**47.53** (9.88)	**46.54** (10.66)	**.000**	**.021**	**1**

* = Significant at $p < .001$.

Note. The mean (standard deviation) score of participants' total score for each EFT phenomenology variable for each delay, along with the p-values for each variable and the associated effect size and statistical power.

Also shown in Table 3.3, is a composite variable consisting of the 5 variables to do with strength and detail of the EFT representation. There was a significant effect of delay on this *representation richness* variable, $F(3, 936) = 6.64$, $p < .001$, $\eta_p^2 = .02$. That is, strength and detail of EFT representations declined with delay. Moreover, the representation richness appeared consistent across the 4 delays, as the variable correlated between .59 and .66 using a simple pairwise Pearson test across these delays. In sum, only 5 of the 10 EFT phenomenology predictions were confirmed: spatial context (H2e), temporal context (H2f) and representation richness (H2g) decreased with delay, and only emotional valence (H2i) personal importance (H2j) increased with delay.

3.3.3.4 RELATIONSHIP AMONG THE CONSTRUCTS

The previous sections have looked at the effect of delay on discounting, EFT and construal preferences. There was a clear effect of delay on discounting, following a typical hyperbolic shape. That is, there were steeper declines in valuation for shorter delays than longer delays, meaning a monetary value to-be-received in a year's time has dropped 50% in valuation. However, the effect of delay on EFT and construal was weaker.

The final part of this study sought to examine whether either discounting, EFT or construal level were related to one another in terms of individual differences. The three constructs were collapsed across the 4 delays to get *one* measure for each of them, irrespective of delay. EFT and construal level *each*, irrespective of time, so they could be correlate with one another (see Table 3.5). Correlations were preferred over regression analyses because the aim was not to predict discounting from EFT or construal levels as such, but merely explore the relationship between the constructs.

There was no relationship between discounting and episodic *representation richness* (the trend was actually in the opposite direction to the predictions), but there was a significant positive relationship between preferring high-level construal and greater strength and detail of EFT representations. That is, all three key predictions (H1a-c) were rejected. Post-hoc power analyses showed that all of the aforementioned correlation analyses were powered sufficiently (n = 313, α = .05, 1 - β = 1).

Age only significantly correlated with EFT richness, and gender only significantly correlated with discounting. Thus, the relationship between EFT richness and high-level construal was not mediated by age or gender. Table 3.4 shows the means within and across these groups.

Table 3.4: Means (St.dev) for all participants, per gender and age group.

		EFT Richness	Discounting	High-level construal	*N*
Gender					
	Female	192.93 (35.34)	-5.07 (1.73)	.20 (7.71)	138
	Male	188.90 (33.95)	-5.54 (1.81)	-.23 (7.77)	172
Age					
	19-39	188.47 (34.72)	-5.30 (1.86)	.09 (7.46)	219
	40-66	195.77 (33.65)	-5.46 (1.64)	-.37 (8.32)	91
Total		190.82 (34.61)	-5.34 (1.80)	-.01 (.50)	313

Note. The bottom rows show the average EFT Richness score, Discounting rate log(k) and high-level construal preference across delays for all participants. The above rows show the averages score within female, male and ages 19-39 and 40-66. Higher EFT Richness score mean greater EFT richness, higher discount scores mean more discounting and higher high-level construal scores mean more high-level construal choices over low-level construals.

Table 3.5: Correlations among EFT, construal and discounting.

	High-level construal	Discounting	Gender	Age
EFT Richness	**.20****	.11	-.06	**.17****
High-Level Construal	-	.07	-.03	.03
Discounting			**-.13***	-.04

* = Significant at p < .05. ** = Significant at p < .01.

Note. Correlations among overall EFT, construal and log(*k*) discounting in Study 1. Each of the 3 variables were collapsed across delay in order to produce one individual difference measure each, irrespective of delay. Significant correlations are highlighted in bold.

3.3.4 DISCUSSION

This study explored the relationship between three key intertemporal choice constructs: delay discounting, EFT and temporal construal. The effects of delay on each of these variables individually were in the directions predicted: longer delays were associated with lower valuations, less rich EFT representations and (weakly) higher-level construals. The effects of delay and magnitude upon valuation was consistent with typical findings in the research literature. Also consistent with the existing research was the decrease in richness and increase in personal importance and emotional valence for EFT representations with increased delay. The effect of delay on construal was weak, however. There was no observed relationship between discounting and self-reported strength and detail of EFT representation, nor construal preferences. There was however a weak relationship between construal and EFT, where greater representation richness correlated positively with more high-level construals.

With 313 participants, after 2 were excluded, it is unlikely that the failure to replicate the effect of delay upon construal and some of the EFT phenomenological variables was down to an insufficient sample size. While the present study had 8 events for EFT, D'Argembeau and Van Der Linden (2004) had 4 future events per 40 participants, and while the present study had 12 construal activities, Liberman and Trope (1998) had 24 activities per 24 participants.

While existing research has shown that individuals discount less when the outcomes are represented episodically. the present study suggests that the unexplained variability in discount rates in the population cannot be explained by variability in EFT. Thus, discounting does not appear to be related to the vividness of future representations that participants spontaneously generate in discount tasks. This explanation is consistent the normal discount rates of patients who cannot construct episodic representations of the future.

The above conclusion is not without its potential problems. Mainly, the use of tasks that are conventionally used within each of the three research areas to measure discounting, EFT and construal. These tasks are not usually presented to participants in conjunction, and so there is a possibility for carryover effects from one task to the other. For instance, the failure to replicate an effect of delay upon construal could be due to the preceding EFT task making people think episodically about their future, also made people construe things in more detail and thus lower-level construal in the succeeding construal level task. It is also possible that the within-subjects design made participants more aware of delay as a variable, and this could have influenced correlations. While it is unclear how the within-sample design may have affected results, it is the major difference from when the measures have been used separately in the literature to identify an effect of delay. In sum, the findings suggested that EFT and construal variability were not related to discounting behaviour.

3.4 STUDY 2

The previous study explored whether individual differences in temporal construal and EFT could account for individual differences in discount rates. Even though discounting, representation richness (EFT) and temporal construal were all, to varying degrees, affected by delay, the individual differences in discounting was not related to individual differences in EFT and temporal construal. The present study is an extension of the previous study, where the aim is still to explore whether individual differences in discounting can be accounted for by individual differences in EFT and temporal construal. This was done by changing the temporal construal task, and by introducing more EFT related tasks, and see if the two constructs then could account for discount rates. It could be that the previous study found no relationship between discounting and EFT because people might not spontaneously engage in EFT in discounting tasks. And so this study seeks to explore this by promoting EFT while participants choose between smaller-sooner and larger-later options.

3.4.1 RATIONALE

Three issues prompted a follow-up study on *Study 1*. First, while *Study 1* showed no relationship between discounting and either EFT richness or construal, the weakness of relationship between delay and construal was concerning. While Liberman and Trope (1998) were able to demonstrate this effect, it could be that the construal preference measure was not as effective in capturing construal preference for the present study's sample. Therefore, the 2-option construal level classification task was replaced with a more open-ended version of the task in Liberman and Trope's (1998) Study 1. Here, instead of choosing between two pre-made descriptions, participants wrote their own descriptions of the given events. Later these descriptions were coded by the experimenter as either high-level or low-level construals.

A second aim was to investigate correlations between discounting, EFT and construal *while* discounting choices were made while engaging in EFT. One reason for the absent relationship between discounting and EFT in the previous study might have been because people might not spontaneously engage in EFT when discounting the future. Thus, the present study sought to explore whether individual differences in discounting and EFT are related when people are prompted to engage in EFT while making intertemporal choices. This was done by adapting the episodic tagging procedure of Peters and Büchel (2010), where people are reminded of their personal future plans at the time of the delay of the larger-later option (see section 3.1.4.1.).

In the interest of staying close to their procedure and to produce suitable trials for the main discounting part of the present study, the discounting calibration procedure was also changed. In this experiment, participants' discount rates were estimated for the immediate amount instead of delayed amounts. A difference to the EFT part of the study was that each episodic future thought generating trial had participants give each event a title. This would be used as an episodic tag in the main discounting part of the study. That is, participants were to produce personal future events at specific delays, and these events were later used as 'episodic tags' associated with these delays when they appeared in delay discount tasks. Thus, the delay discounting task will be similar to that of *Study 1*, but some of the trials will have an episodic tag associated with the larger-later delay. By examining the relationship between this episodic tagging effect and individual differences in discounting, this study explores whether people who discount more are also people for whom the episodic tagging effect is greater.

A third aim was to explore the date/delay effect (Read et al.; 2005; see section 2.3.1.4) in conjunction with the episodic tagging effect in the main discounting part of the study. In section 3.1.4 I considered the possibility that the date/delay effect could be explained by mental time travel. As dates are more difficult to directly compare, people focus less on the waiting period and instead mentally envision the time of receiving the reward as the calendar date reminds them specifically of when this will take place. Thus, if the date/delay effect is caused by episodic future thinking, it should be absent when people are already engaging in episodic future thinking as prompted by episodic tagging. That is if the episodically tagged options in a delay discounting task are written in a date format, it should have the same level of discounting as episodically tagged options written in a delay format.

In sum, the 4 key predictions of this study concern those to do with the relationship between each construct, as well as the 2x2 comparison between episodic tagging and delay-format:

- H1a: Discounting correlates negatively with EFT richness.
- H1b: Discounting correlates positively with high-level construal preference.
- H1c: EFT richness correlates negatively with high-level construal preference.
- H2: There is an interaction effect between delay-format and episodic tagging where the episodic tags (IV1) will reduce discounting in the delay-format but there will be no difference in the date-format (IV2).

Following this, if the episodic tag effect is due to greater episodic richness, and that this correlates negatively with discounting and high-level construals, this predicts that the tag-effect negatively correlates with discounting (H1d) and high-level construals (H1e), and correlates positively with EFT-richness (H1f).

As with Study 1, the confirming the following predictions would merely replicate findings in the literature, and provide evidence that the data is reliable:

Increased delay decreases valuation (H3a), which is greater with delay-formats than date-formats (H3b). Increased delay also increases high-level construals (H3c), as well as emotional valence, personal importance, use of words and coherent story (H3d-f). increased delay decreases autonoetic consciousness, sensory detail, spatial context, temporal context, emotional experience, and the composite representation richness variable (H3g-l). Finally, episodic tags should decrease discounting relative to no episodic tags (H3m).

3.4.2 METHODS

3.4.2.1 PARTICIPANTS

A total of 117 US-resident participants (median age: 31; 41% female) out of 150 recruited participants were included in the dataset. Participants were recruited through Amazon

Mechanical Turk, using the intermediary mturkdata.com to allow non-US requestors to continue to use this participant set. The study was run on December 17, 2014, and participants were paid $4 for completing the 30-minute study.

There were two exclusion criteria. First, participants were excluded if they always chose the smaller-sooner option for one or more trials in the initial discounting block. This would leave no upper bound for their valuation of the delayed outcome, making it impossible to generate appropriate trials for the discounting trials of the final part of the study. Fifteen participants were excluded for this reason. Second, participants were excluded if they gave dates for their chosen personal future events that were either corrupted, in the past or crossed over for their chosen near-future delays and the distant-future delays. Eighteen participants were excluded for this reason.

3.4.2.2 DESIGN AND PROCEDURE

The study consisted of four stages, three of which were similar to Study 1, measuring discounting, construal level and EFT phenomenology. The initial discount measure also included a date/delay manipulation, measuring the date/delay effect. The fourth stage measured the episodic tag effect. The discounting, EFT phenomenology and episodic tag measures used the same 4 delays (1 week, 1 month, 3 months, 1 year), whereas the construal level measure only used 2 delays (1 day and 1 year). Delays were varied within participants. Each measure is detailed in the following 4 sections.

3.4.2.2.1 Discounting calibration

The measure for discount rates was similar to *Study 1* in that the task consisted of binary choices between smaller immediate sums of money and larger-later sums. However, following the procedure of Peters and Büchel (2010, 2010), instead of adjusting the immediate sum of money, this was kept fixed at $20. The larger-later sum was varied to establish the delayed sum of money that was equivalent to $20, for a given participant, in order to identify their discount rate. This was done for each of the 4 delays (7 days, 30 days, 90 days, 365 days). Following this stage, the experiment was programmed to generate a best-fit value for *k*, which had been done offline for the responses in *Study 1*. This value of *k* was used to generate trials in the final discounting part of Study 2.

For half of the participants, the delays were written as number of days (day-format) and for the other half delays were written as specific calendar dates (date-format). This between-subjects manipulation was maintained for the final delay-discounting task with episodic tags.

3.4.2.2.2 Temporal construal

The second task of Study 2 measured construal level preference. This task was based on Study 1 of Liberman and Trope's (1998) original Construal Level Theory Paper. Participants were instructed to write descriptions of 10-100 characters for each of a series of activities presented to them. They were initially presented with an example, "Making a list", along with several potential descriptions for such an activity: "Getting organised", "Writing things down", "Trying to make sure I don't forget something", "Finding some paper and a pen".

A total of 8 activities were presented to participants, of which 7 were used by Liberman and Trope (1998). To keep the study at a reasonable duration, and to maximise the power to detect effects of delay, only two delays were used in this task: 1 day and 1 year. Thus, 4 activities were described per delay, for each participant. Activity allocation to one of the two delays was randomised. Delays were presented in blocks of 4 activities, and the order of delays were randomised.

3.4.2.2.3 Episodic future thinking

The third part measured EFT phenomenology. This task was carried out very similarly to that of Study 1, but also drawing from the procedure of Peters and Büchel (2010). As before, participants were instructed to think of 4 neutral or positive events they anticipated experiencing in their own personal future, at four different time periods. They were asked to think of personal future events in "3 to 7 days' time", "14 to 28 days' time (2 to 4 weeks' time)", "30 to 90 days' time (1 to 3 months)", "180- 365 days' time (6 to 12 months)". One of four cue words were presented ahead of each future event generation, which participants could ignore or use to help them think of an event.

Also as before, participants were given 30 seconds, with an on-screen timer, to visualise their chosen event before writing down their descriptions, as in Study 1. However, here they also had to give each event a 4-15 character label, and chose from a calendar exactly when the vent would occur. This label and its associated delay was later used as an EFT tag in the fourth and final part of the study. At the end of the EFT part of the study, participants filled out the same questionnaire about vividness and concreteness as in Study 1.

3.4.2.2.4 Delay discounting and episodic tags

Finally, in the fourth part of the study, discount rates for episodically tagged outcomes were compared with untagged outcomes. There were 40 trials in total, for which the structure was based upon Peters and Büchel (2010). In all trials, participants chose between a fixed hypothetical immediate sum of $20 and a delayed sum of money determined by the *k* value estimated for the given participant in part 1 (see section 3.3.2.2.2). For half the trials, the larger-later option was accompanied by an *episodic tag*, serving as a reminder of what the given participant would do at that specific delay. These tags were generated in part 3.

Figure 3.4: An example of an untagged and a tagged trial.

Example: an untagged trial

$20	$20
immediately	in 7 days
	XXXXXXXX

Example: a tagged trial

$20	$20
immediately	in 7 days
	FLY HOME

Note. An example of what a trial in the untagged condition and a trial in the tagged condition might look like. Note that this is not a direct screenshot from the experiment, but the relative layout remains the same as in the experiment.

For example, if a participant had labelled one of their personal future events with "FLY HOME" for the delay "in 7 days" in the previous EFT stage, a trial in this episodic tag stage would have a larger-later option where the delay was "in 7 days" with their personalised episodic tag "FLY HOME" written directly underneath it (see Figure 3.4).

For each of the four delays, 5 trials were generated using different sums of money for the delayed option, with the median sum of money set as the participants' predicted indifference pint for that delay. As for the remaining 4 sums, there were two larger and two smaller sums of money, uniformly distributed. Thus, if participants made choices in accordance with hyperbolic discounting with the values of k calculated for them in Part 1, they would be expected to prefer the smaller-sooner outcome for two of the five trials, the larger-later outcome for two of the trials, and be indifferent between options for one of the trials. This approach meant that any miscalibration would be unlikely to lead to all smaller-sooner or all larger-later choices.

Untagged delays were generated by taking the tagged delays and randomly adding or subtracting 1, 3, 8 or 16 to each of the four delays. The same procedure as above for generating five trials with different delayed amounts for each delay was used. For these trials, the delayed amount and delay were accompanied by the text "XXXXXXXX" in place of an episodic tag.

Corresponding with the initial discounting calibration task, participants were either presented with delays in a day-format or in a date-format in order to explore the date/delay effect further. Thus, participants would only be presented with delays as either days or dates across the entirety of Study 2.

3.4.3 RESULTS

3.4.3.1 INITIAL DISCOUNTING

For the discount rate measures, median discounting k was 0.007 $days^{-1}$, comparable with that seen in Study 1. The effect of delay upon valuation was significant, $F(3, 348) = 42.40$, $p < .001$, $\eta_p^2 = .268$, as participants demanded greater rewards with greater distance from the presence. This effect is illustrated in Figure 3.5 and the means are in Figure 3.6. The analysis was well powered according to post-hoc power analysis (n = 117, $\alpha = .001$, $1 - \beta = 1$). There were 67 participants in the day format condition, and 50 participants in the date format condition. Comparing log(k) there was no effect of date/delay format, $t(115) = .34$, $p = .73$, d

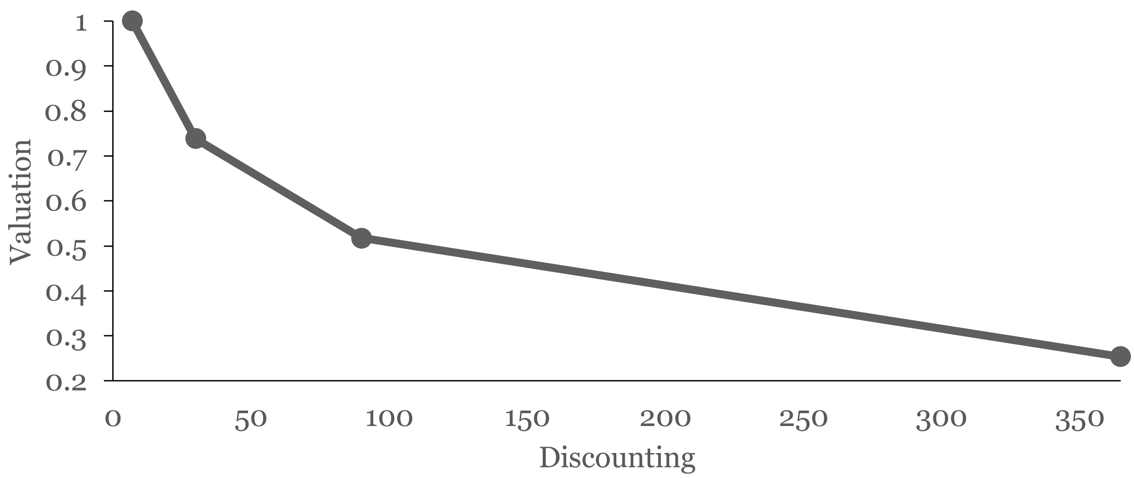
= .063, and the post-hoc power analysis showed that this t-test was slightly underpowered (α = .05, 1 - β = .726). Subsequent analyses of Study 2 collapse across this variable (see discussion). Thus, while the effect of delay upon valuation was replicated (H3a), this study failed to replicate the date-delay effect (H3b).

Table 3.6: Descriptive values for the immediate value of $20 per delay.

	1 week (7 days)	1 month (30 days)	3 months (90 days)	1 year (360 days)
Mean	26.69	36.15	51.15	105.37
St.dev.	11.05	27.96	54.65	114.37

Note. The mean and standard deviation for the valuation of $20 across the four delays. For instance, valuing the immediate value of $20 as $51 in 3 months means that participants on average chose demanded $51 in 3 months in order to forego $20 immediately.

Figure 3.5: Mean proportionate valuations across the four delays.



Note. Mean proportionate valuations of $20 for each delay (1 day, 1 week, 1 month, 1 year), relative to the score on the day 1 delay. With greater delay, the more people, on average, discounted the reward.

Note that this graph is for illustrative purposes only. The means have been transformed to show the change in valuation over time. See Table 3.6 for the actual means and standard deviations for each of the delayed rewards.

3.4.3.2 TEMPORAL CONSTRUAL

Participants' descriptions of near and distant future activities were hand-coded for construal level by the experimenter. The descriptions fitting the '[description] by [activity] frame' were coded as *high-level construals*, and those fitting the '[activity] by [description] frame' as *low-level construals*, and the remaining descriptions were coded as *neither*. For example, if the description to an activity such as "Moving into a new apartment" was described as "starting a new life" it would be coded as a *high-level construal*, whereas the description "Packing boxes" would be coded as a *low-level construal*. A description such as "Moving to a different town" would be coded as *neither*. Overall, 67% of descriptions were coded as either low-level or high-level construals.

While Study 1 showed a weak effect of delay on construal, there was no effect of delay on construal in Study 2 either, though it is worth mentioning that there was more noise in the data this time. Participants included in this analysis were the ones for whom could be coded at least 2 of the 4 responses for each delay as either low- or high-level construals. Comparing the proportion of low-level construals (low-level construals divided by the total number of responses that could be coded for each delay) for one day and one year delays, there was a non-significant trend towards greater use of low-level construals for short delays (.45 of short-delay trials) than long delays (.42 of long-delay trials), $Z = -1.05$, $p = .29$. The prediction from the construal level literature was not confirmed (H3c). The preference ratings correlated at .78, suggesting construal measures were consistent for the two delays. However, the statistical power was very weak according to the post-hoc power analysis ($n = 87$, $\alpha = .05$, $1 - \beta = .15$).

3.4.3.3 EPISODIC FUTURE THINKING

As with Study 1, participants' EFT self-reported phenomenology scores were measured for each of the 9 phenomenological experiences of interest, as well as a composite variable for representation richness. Table 3.7 and Figure 3.6 shows the effect of delay on self-report-based measurements of EFT phenomenology.

Qualitatively, the effect of delay on EFT was similar to that found in *Study 1*. However, in the present study, the effect of delay on the representation richness composite variable did not reach significance, $F(2.8,321) = 2.12$, $p = .10$, $\eta_p^2 = .018$. Consistent with *Study 1*, reported spatial context, $F(2.8, 318) = 2.78$, $p = .041$, $\eta_p^2 = .023$, declined significantly with delay, and emotional valence, $F(2.8, 348) = 3.05$, $p = .029$, $\eta_p^2 = .026$, and personal importance was higher at longer delays than at shorter delays, $F(2.7,266) = 7.36$, $p < .001$, $\eta_p^2 = .060$. All of the above were applied Huynh Feldt corrections for violations of sphericity.

The decline of sensory detail with delay was marginally significant, $F(3, 348) = 2.60$, $p = 0.52$, $\eta_p^2 = .022$. As in Study 1, when comparing each phenomenological measure of EFT from 1 day to 1 year into the future, the only variable that subverted predictions was *emotional experience* ($p = .807$, $\eta_p^2 = .003$), which increased rather than decreased with delay. The representation richness variable correlated between .44 and .66 across the different delays, thus appearing consistent across delays. Thus only 3 out of 10 predictions from the EFT research literature were confirmed and replicated in the present study.

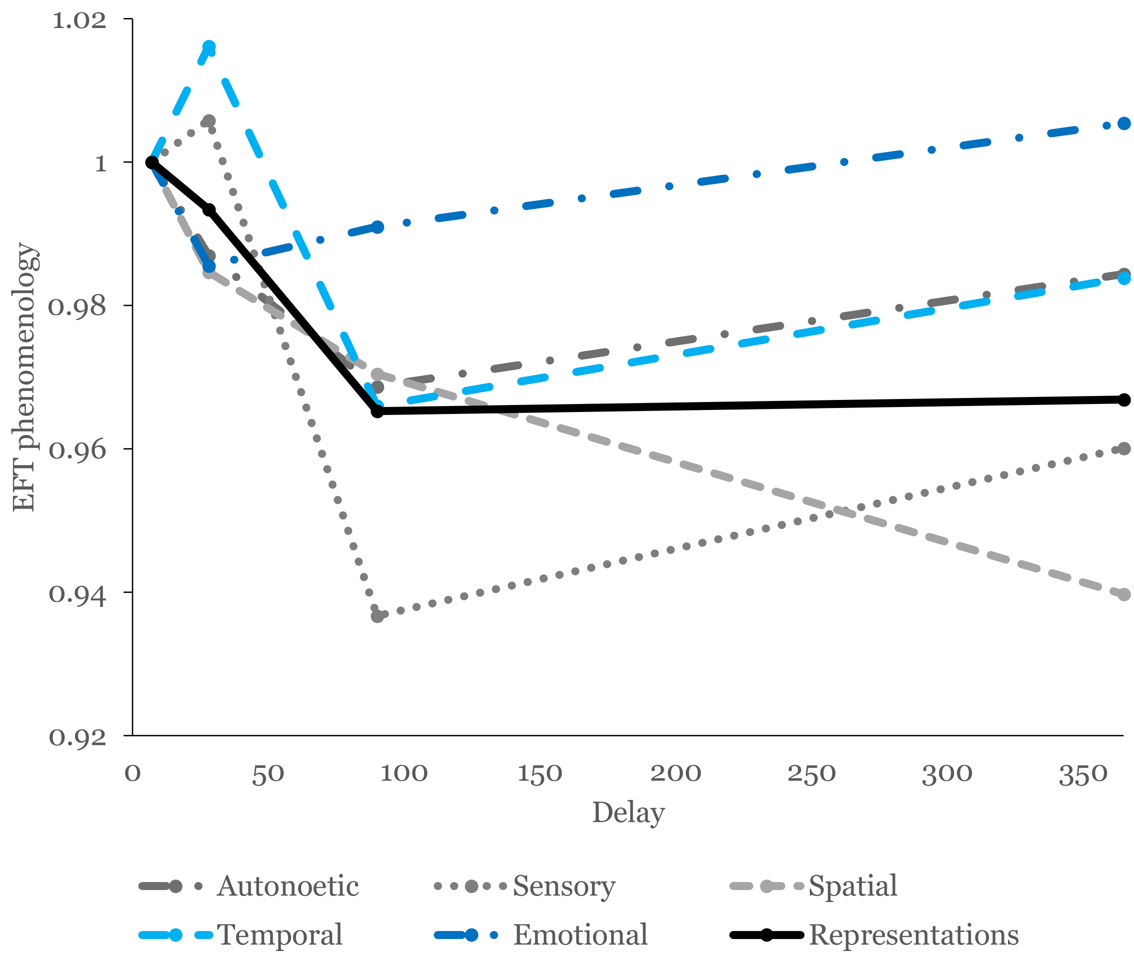
Table 3.7: Average score on each EFT phenomenology per delay.

	1 week (7 days)	1 month (30 days)	3 months (90 days)	1 year (360 days)	*p*	η_p^2	1 - β
Autonoetic consciousness	11.50 (2.56)	11.35 (2.50)	11.14 (1.60)	11.32 (2.74)	.896	.008	.708
Sensory detail	10.27 (2.89)	10.33 (2.76)	9.62 (2.83)	9.86 (3.17)	.520	.022	.953
Spatial context*	**16.92** (3.52)	**16.66** (3.44)	**16.42** (3.25)	**15.90** (4.18)	**.041**	**.023**	**.960**
Temporal context	5.58 (1.69)	5.67 (1.48)	5.39 (1.56)	5.49 (1.63)	.475	.007	.378
Emotional experience	5.54 (1.32)	5.46 (1.30)	5.49 (1.27)	5.57 (1.45)	.807	.003	.255
Emotional valence*	**6.04** (1.18)	**6.05** (1.18)	**5.95** (1.33)	**6.31** (1.05)	**.029**	**.026**	**.971**
Personal importance**	**5.26** (1.62)	**5.17** (1.53)	**5.50** (1.56)	**5.84** (1.34)	**.000**	**.060**	**1**
Use of words	4.82 (1.68)	4.96 (1.60)	4.81 (1.72)	5.03 (1.70)	.272	.011	.890
Coherent story	5.03 (1.59)	4.88 (1.63)	4.99 (1.63)	5.22 (1.67)	.127	.016	.937
Representations	49.80 (9.57)	49.47 (8.72)	48.07 (8.29)	48.15 (10.61)	.100	.018	.949

* = Significant at p <.05. ** = Significant at p <.001.

Note. The mean (standard deviation) score of participants' total score for each EFT phenomenology variable for each delay, along with the p-values for each variable and the associated effect size and statistical power.

Figure 3.6: The representation richness variable and the 5 individual variables.



Note. The 5 individual representation richness variables (autonoetic, sensory, spatial, temporal, and emotional) along with the representation richness variable, across 4 delays (1 week, 1 month, 3 months, 1 year). All but emotional experience decreased with delay. Note that this graph is for illustrative purposes only. The means have been transformed to show the change in valuation over time. See Table 3.7 for the actual means and standard deviations for each of the phenomenological measures.

3.4.3.4 DELAY DISCOUNTING AND EPISODIC TAGS

This part of the experiment measured participants' discount rates when the delayed options in the discounting choice trials were tagged with *episodic tags* within-subjects to when they were *not* tagged. The effect of this tag was examined by counting the number of times '$20 immediately' was chosen over the delayed amount across the 20 trials with episodic tags. This number was compared with the number of times the same choice was made for the 20 control trials where 'XXXXXXXX' was presented in place of the episodic tag. The monetary value for the delayed options were based on the individual participant's discount rates from the initial discounting calibration procedure. The values were generated with the aim to have equal numbers of smaller-sooner and larger-later choices, as Peters and Büchel (2010) did. Among the 20 trials presented per condition, the mean number of smaller-sooner choices was 11.2 in the untagged condition, and 9.6 in the tagged condition. The episodic tag effect was replicated (H3m), where people discounted significantly less in the tagged condition than in the untagged condition, $t(116) = 5.42$, $p < .001$, $d = -.501$. Post-hoc power analysis showed that this was well-powered ($n = 117$, $\alpha = .05$, $1 - \beta = 1$).

3.4.3.5 RELATIONSHIP AMONG THE CONSTRUCTS

Lastly, this study examined the relationship between EFT, construal, initial discounting, and the magnitude of the episodic tag effect (number of larger-later choices in the tagged condition – number of larger-later choices in the untagged condition). As with Study 1, the aim was to explore the relationship between the constructs rather than predicting one from the other. No significant effects were found, although the trend towards a positive correlation between EFT richness and tag effect was similar to that found by Peters and Büchel (2010). Thus, the remaining 3 key hypotheses were not confirmed (H1a-c).

Table 3.6 shows correlations among the variables discounting, construal and EFT. As in *Study 1*, the correlations are weak, and in the case of *Study 2*, all are non-significant. Thus, the relationship from *Study 1* between EFT and construal is not replicated here when using a different construal measure. As with *Study 1*, the results suggest that the three constructs are not strongly related. Neither age nor gender correlated with any of the constructs.

According to post-hoc power analyses, all 4 of the 6 correlations of interest were powered sufficiently ($n = 117$, $\alpha = .05$, $1 - \beta = .94$-1), except for the correlations between high level construal and either EFT richness ($1 - \beta = .591$) or discounting ($\beta = .743$).

Table 3.8: Means (St.dev) for all participants, per gender and age group.

		EFT Richness	Discounting	High-level construal	Tag effect	*N*
Gender						
	Female	196.56 (29.46)	-2.27 (.63)	.46 (.39)	1.99 (3.27)	48
	Male	194.74 (29.58)	-2.24 (.59)	.59 (.41)	1.32 (3.07)	69
Age						
	19-39	192.53 (30.10)	-2.22 (.63)	.57 (.41)	1.56 (3.15)	97
	40-66	109.85 (21.08)	-2.40 (.45)	.41 (.39)	1.55 (3.24)	20
Total		195.49 (29.42)	-2.25 (.61)	.54 (.41)	1.56 (3.15)	117

Note. The bottom rows show the average EFT Richness score, Discounting rate log(k) and high-level construal preference across delays for all participants. The above rows show the averages score within female, male and ages 19-39 and 40-66. Higher EFT Richness score mean greater EFT richness, higher discount scores mean more discounting and higher high-level construal scores mean more high-level construal choices over low-level construals.

Table 3.9: Correlations among EFT, construal, discounting and tag effect.

	High-level construal	Discounting	Tag effect	Gender	Age
EFT Richness	.04	-.16	.12	-.03	.11
High-Level Construal	-	.06	-.10	.15	-.09
Discounting	-	-	.14	0.21	-.15
Tag effect	-	-	-	.01	-.09

None were significant at $p < .05$.

Note. Correlations among overall EFT, construal, discounting and magnitude of episodic tag effect across participants in Study 1, collapsing across delay for EFT and construal, and using log(k) for discounting. Each of the three variables of interest were collapsed across delay in order to produce one individual difference measure each, irrespective of delay.

3.4.4 DISCUSSION

The results of *Study 2* were generally similar to those of *Study 1*: there was a strong effect of delay in the discounting task, but there was not much effect of delay on construal of the presented activities. There was no effect of delay on EFT richness, but there was a decrease of sensory detail and spatial context with delay, and an increase in emotional valence and personal importance with delay. Collapsing across delay, correlations among the three variables discounting, EFT and construal were very weak.

There was a clear effect of episodic tagging, replicating the findings of Peters and Büchel (2010): Participants discounted less when the delayed outcome was accompanied with an episodic tag, generated by the participant earlier, describing an event they expected to experience in their own personal future, at the time of the delayed outcome. As the present study failed to replicate the date/delay effect, this was not investigated further in this experiment, and so the discounting task with and without episodic tags were collapsed across delays and dates. The failure to replicate the date/delay effect could be attributed to the study being run at the end of the year, so that 3 of the 4 dates were from the following year, increasing psychological distance. Hence, the date/delay effect will be explored again in conjunction with the episodic tagging effect in Study 3.

As in Study 1, there was limited evidence for any effect of delay on construal. There is no indication that participants failed to engage with the task, as nearly all descriptions of the presented activities were meaningful, though not always codeable as low- or high-level construals. One possibility for this failure in finding an effect of delay on construal is that the coding of descriptions in the present study differed from that of Liberman and Trope (1998). Here, many of the descriptions were, in terms of construal, ambiguous. For example, a common description of the activity "Having a party at your apartment" was "getting friends round", which is ambiguous in terms of activity-by-description or description-by-activity. You could have a party by getting friends round, or you could get friends round by having a party. Also, another potential explanation is that running the study within-subjects reduces this effect.

This experiment lost a considerable number of participants, from initial 150, 33 were excluded from the main data set, leaving 117, which was further reduced to 87 participants in the construal level task. However, Liberman and Trope (1998) found an effect of delay upon construal with only 7 activities per 32 participants. The present study had 8 construal activities. The same goes for the date/delay-effect which was originally detected with only 4 trials and 30 participants per condition (Read et al., 2005), where the present study had 50 and 67 participants in each delay-format condition. Finally, 117 participants for the EFT phenomenology measures should have been sufficient relative to 40 participants used in the literature (both had 4 future events; D'Argembeau & Van Der Linden, 2004). Thus, it is unlikely the failure to replicate these three effects was due to the small sample size per se. However, the high exclusion rate (1 in 5 participants) suggests poor data quality overall. The remaining participants, despite passing the exclusion criteria, could still have been giving poor quality responses and engaged poorly with the tasks.

So far, both studies have successfully replicated the effect of delay upon value with lower valuation with increasing delay. Study 1 showed a weak effect of delay upon construal, where there were more lower-level construals for the near future and more high-level construals for the distant future. However, when using a more open-ended version of the task in Study 1, Study 2 did not find this effect, although trend was in the same direction. While representation richness of EFT decreased significantly with delay in Study 1, this did not reach significance in Study 2. Among the individual phenomenological variables, temporal context decreased with delay in Study 1 and Sensory detail decreased with delay in Study 2. However, both studies found that spatial context decreased with delay, whereas emotional valence and personal importance increased with delay. All nine variables were trending in the predicted directions, except emotional experience which descriptively appeared rather consistent over time. Neither study found that individual differences in discounting was related to EFT nor construal, although Study 1 found greater high-level construal amongst those who scored higher on representation richness. Finally, there was a successful replication of the episodic tagging effect with an efficient online based method where people discounted less when larger-later options were accompanied with episodic tags to remind them of future plans, compared to when there were no such tags. A key issue to address in the third and final study of this strand of research is the failure to replicate the effect of delay upon construal, twice, as well as the failure to replicate the date/delay effect.

3.5 STUDY 3

3.5.1 RATIONALE

As with *Study 1*, *Study 2* did not show any relationship between discounting and the constructs EFT and construals, despite using a more open-ended version of the construal measure, and when prompting participants to engage in EFT while make intertemporal choices. It is possible that while EFT and construal levels are affected by time in conventional laboratory-based studies, these measures do not engage participants in online studies. I therefore ran a final study on discounting, construal and EFT in the lab, using the same discounting measure of *Study 2*, the same construal level measure of *Study 1*, and the same EFT and episodically tagged discounting tasks of *Study 2* (section 3.5.2). The changes made are listed below.

This study reduced the number of delays in the EFT and construal tasks from 4 to 2 points in time, to allow for more trials for each of these delay conditions. This was done because this study was lab-based, rather than online-based, and not as many participants could be recruited. This allowed for a more accurate estimate of the effect of delay without risking participant fatigue as these tasks require considerable mental effort and engagement in order for the mental representation measures to work.

The study also sought to explore the date/delay effect (see section 2.3.1.4) in context with the episodic tag effect. Peters and Büchel (2010) proposed that the date/delay effect could be a result of the dates-format (rather than conventional delay-format) making people engage in EFT. Perhaps instead of being presented with “90 days”, a specific date such as “20 February 2021” reminds people of their personal future plans at that point in the future, and thus prompts EFT. This was also explored in the rationale for Study 2. As in Study 2, this particular issue was explored by having a between-subjects manipulation for the discounting- and episodic tag generation tasks presented participants with delays either in the form of number of days (delay condition) and as specific calendar dates (date condition).

This manipulation will be referred to as *delay format* and the delay condition will be in a *day-format* and the date condition in a *date-format*.

The 4 key predictions are the same as in Study 2, concern the relationship between each construct, and the 2x2 episodic tagging and delay-format comparison:

- H1a: Discounting correlates negatively with EFT richness.
- H1b: Discounting correlates positively with high-level construal preference.
- H1c: EFT richness correlates negatively with high-level construal preference.
- H2: There is an interaction effect between delay-format and episodic tagging where the episodic tags (IV1) will reduce discounting in the delay-format but there will be no difference in the date-format (IV2).

As in Study 2, if the episodic tag effect is due to greater episodic richness, and results show that this correlates negatively with discounting and high-level construals, the tag-effect should be negatively correlated with discounting (H1d) and high-level construals (H1e), and it should correlate positively with EFT-richness (H1f).

And as with Studies 1-2, the following predictions would just replicate general effects that are already known form the research literature, but if they are supported, they provide evidence that the data is reliable:

Increased delay decreases valuation (H3a), which is greater with delay-formats than date-formats (H3b). Increased delay also increases high-level construals (H3c), as well as emotional valence, personal importance, use of words and coherent story (H3d-f). Finally, increased delay decreases autonoetic consciousness, sensory detail, spatial context, temporal context, emotional experience, and the composite representation richness variable (H3g-l).

3.5.2 METHODS

3.5.2.1 PARTICIPANTS

The dataset included 63 out of the UK-based participants (median age: 25; 63% female) tested in a laboratory setting at City University of London, between March and June 2016.

They were paid £8 by the hour for completing the 40-minute-long study. As with Study 2, participants were excluded if they failed to place their chosen personal events in the future for the EFT task. Five participants were excluded for this reason.

Study 3 was carried out simultaneously, with the same participants, as Study 4. All participants completed Study 4 first, with a break to avoid any unforeseen carryover effects from Study 4. Moreover, the literature suggests incidental values do not affect temporal judgements (Matthews, 2012; Alempaki et al., 2019).

3.5.2.2 DESIGN AND PROCEDURE

Study 3 was similar to Study 2 as the experiment consisted of 4 stages measuring discounting, the date/delay effect, construal level, EFT phenomenology and the episodic tag effect. However, in Study 4, only discount rates and the effects of date/delay and episodic tagging were across 4 delays (1 week, 1 month, 3 months, 1 year) while EFT phenomenology and construal level preference were measured across 2 delays (1 day and 1 year). As with Study 1 and 2, all delay conditions were conducted within-participants. Each measure is detailed in the following 4 sections.

3.5.2.2.1 Discounting calibration

This part of the study measured discount rates exactly as in Study 2. In short: binary choices between smaller-sooner ($20 immediately) and larger-later sums of money, once for each of the 4 delays: 7 days, 30 days, 90 days, 365 days. A value of k was generated from this calibration, used later to produce trials in the final episodically tagged discounting task.

3.5.2.2.2 Temporal construal

This study returned to the construal level preference measure used in Study 1 (see section 3.3.2.2.1), originally derived from Liberman and Trope's (1998) study 2. In short: participants were presented with an activity along with 2 descriptions of this activity, and their task was to choose which one they preferred. A total of 40 such trials were presented, 20 of which were from Liberman and Trope's (1998) study, and 20 were new to the present study. The events were randomly allocated to one out of two delays (1 day, 1 year), and the order of delays were blocked an randomised. The left-right order of the construal level options were also randomised. Lastly, participant indicated their preference for the choice made on a sliding scale.

3.5.2.2.3 Episodic future thinking

The measure of EFT phenomenology was carried out largely similar to that of Study 2, which in turn was similar to Study 1. The main difference here was reducing the number of delays from 4 to 2. Thus, the 4 personal future events participants thought of would occur in either 1 day (3-7 days) or 1 year (6-12 months). As in Study 2, episodic tags were generated for each event, which would later be sued in the *episodic tagging discounting* part of the experiment.

3.5.2.2.4 Delay discounting and episodic tags

This measure of the effects of episodic tagging and date/delay format was identical to that of Study 2, but with a few crucial differences. One, the delayed options were either in 3-7 days or 6-12 months. Second, these delays as well as the immediate option delay were written either in number of days, or in terms of *dates*. The date/delay manipulation was between-subjects, whereas the episodic-tag manipulation was, like Study 2, within-subjects. Thus, a *delay* condition trial could read like "£20 immediately or £39 in 390 days Graduation", and a *date* condition trial could be "£20 immediately or £24 on June 17 2016 Exams". Both of these examples are episodically tagged, whereas in the un-tagged condition they would have a "XXXXXXXX" in place of the episodic tags.

3.5.3 RESULTS

3.5.3.1 INITIAL DISCOUNTING

As a measure of discounting, a value of *k* was calculated for each participant, of which the median of 0.009 days $^{-1}$.was comparable to those of Study 1 and Study 2. There was a significant effect of delay on valuation, comparable to Study 2, $F(3, 186) = 26.55$, $p < .001$, $\eta_p^2 = .300$, confirming the hypothesis based on the discounting literature (H3a). As before, the distribution was skewed, so the values of *k* were log transformed before comparing the means.

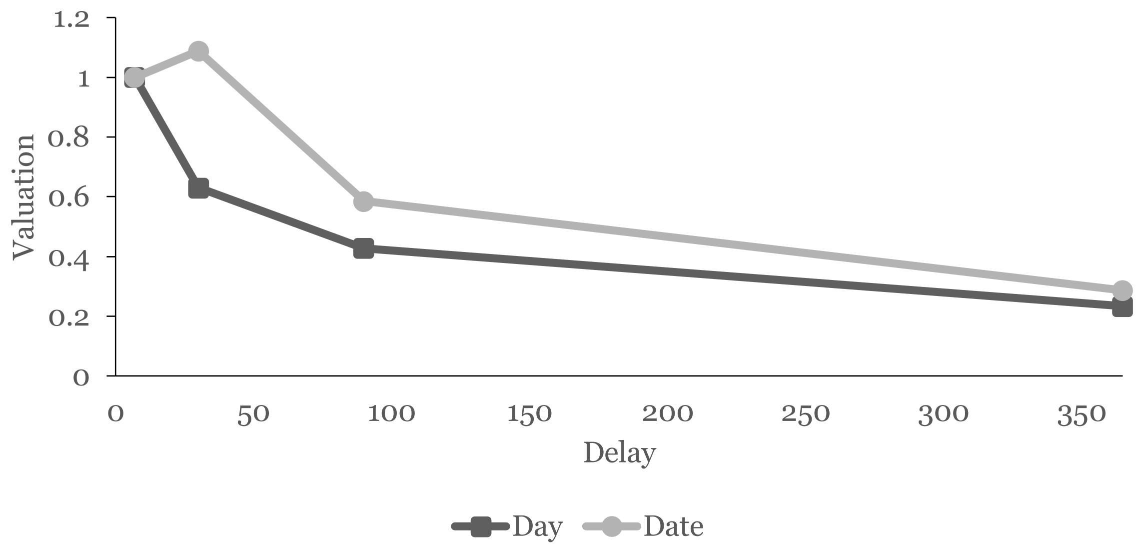
There were 31 participants I the date condition and 32 in the delay condition. An effect of delay format was found, where people discounted less in the *date* format (M = -1.86) than those in the *day* format (M = -2.46), $t(61) = 3.70$, $p < .001$, $d = .932$, confirming the hypothesis (H3c). Both the ANOVA ($n = 63$) and the t-test ($n1 = 31$, $n2 = 32$) were sufficiently powered according to post-hoc power analysis ($\alpha = .001$, $1 - \beta = 1$). Because the date/delay was replicated in this study, the analysis could carry on to compare the episodic tag effect and the date/delay effect in section 3.5.3.4.

Table 3.10: Descriptive values for the immediate value of $20 per delay.

	1 week (7 days)	1 month (30 days)	3 months (90 days)	1 year (360 days)
Mean	35.55	46.05	73.34	139.94
St.dev.	48.53	63.42	107.96	139.98

Note. The means and standard deviations for the valuation of the immediate sum of £20 either 1 week, 1 month, 3 months or 1 year into the future. Valuing the immediate reward of £20 as £46 in 1 month means that participants demanded £46 in one month in order to forego £20 immediately.

Figure 3.7: Mean proportionate valuations for the day and date condition each.



Note. In the delay condition, valuations of the delayed reward decreased with increased delay. This drop with delay was less steep for the date condition.

Note that this graph is for illustrative purposes only. The means have been transformed to show the change in valuation over time. See Table 3.10 for the actual means and standard deviations for each of the delayed rewards.

3.5.3.2 EPISODIC FUTURE THINKING

As in Studies 1 and 2, participants' self-reported EFT phenomenology scores were measured for each of the delays, which in the case of Study 3 was 1 day and 1 year. Table 3.11 and Figure 3.8 shows the effect delay had on the self-report-based measurements of EFT phenomenology, of which the effect was comparable to that of Study 1 and Study 2. As before, there was no significant effect of delay on autonoetic experience, emotional significance, use of words or coherent story. Like Study 1, but unlike Study 2, there was no effect of delay on sensory representations, but temporal context was significantly affected by delay, $t(62) = 2.34$, $p = .023$, $\eta_p^2 = .294$. Unlike Study 1, but like Study 2, there was no effect of delay on the composite representation variable.

However, consistent with Study 1 and 2, there were significant effects of delay on spatial context, $t(62) = 2.01$, $p = .042$, $\eta_p^2 = .262$, emotional valence, $t(62) = -3.51$, $p = .001$, $\eta_p^2 = -.443$,and personal importance, $t(62) = -5.05$, $p < .001$, $\eta_p^2 = -.637$. Thus, in short, participants experienced less spatial and temporal context with delay, whereas emotional valence and personal importance increased with delay.

Correlating the two delays of each phenomenological measure ranged between .25 and .78, and all correlations were significant, $p < .001$ (except emotional valence, $p = .014$, and personal importance, $p = .049$). Thus, the measurements appeared consistent across the two delays. Post-hoc power analyses were carried out on each of these t-tests ($n = 63$, $\alpha = .05$) and showed that only the tests for the emotional valence ($1 - \beta = .999$) and personal importance ($1 - \beta = .999$) measures were powered sufficiently (see Table 3.11).

In sum, only 4 out of the 10 predictions based on the EFT research literature were confirmed and replicated: spatial context and temporal context decreased with delay and emotional valence and personal importance increased with delay.

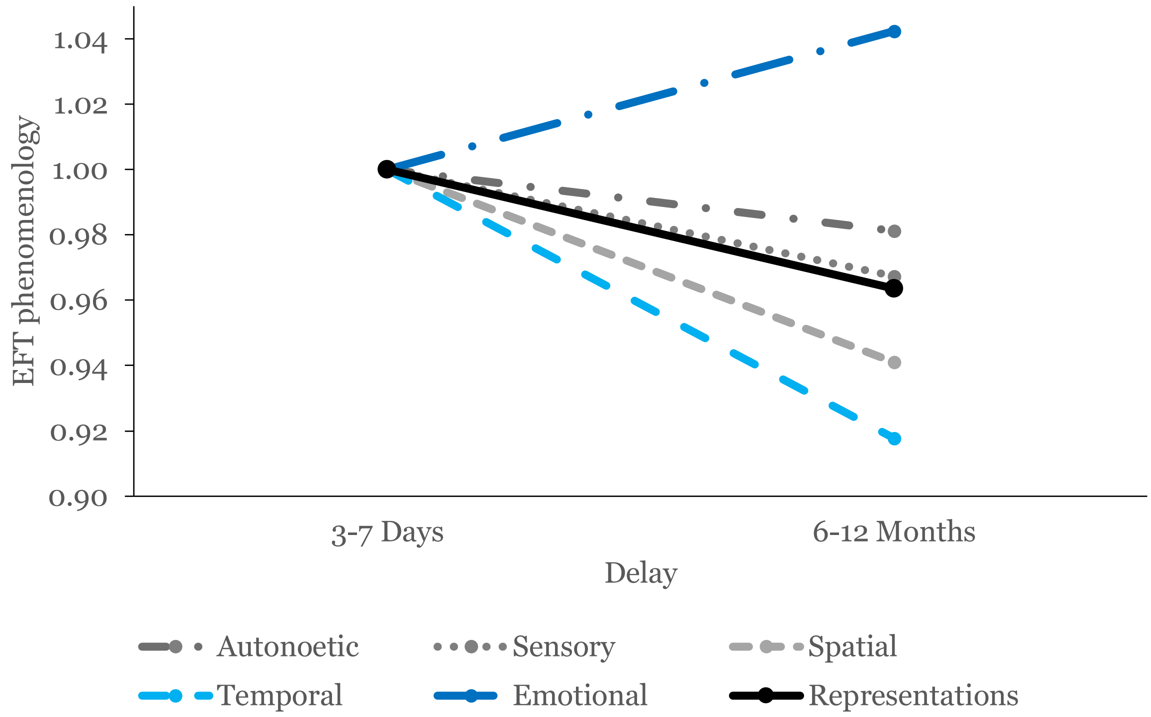
Table 3.11: EFT phenomenology for the two delays.

	3-7 Days	6-12 Months	*p*	η_p^2	1 - β
Autonoetic consciousness	20.25	19.87	.491	.087	.105
	(4.66)	(5.34)			
Sensory detail	19.00	18.38	.228	.153	.223
	(4.54)	(4.64)			
Spatial context*	**30.87**	**29.05**	**.042**	**.262**	.535
	(6.26)	(7.00)			
Temporal context*	**10.46**	**9.60**	**.023**	**.294**	.632
	(3.28)	(3.01)			
Emotional experience	9.44	9.84	.219	-.156	.230
	(2.77)	(2.800)			
Emotional valence**	**11.03**	**12.13**	**.001**	**-.443**	.933
	(2.21)	(1.99)			
Personal importance*	**9.03**	**11.49**	**.000**	**-.637**	.999
	(3.13)	(2.41)			
Use of words	7.94	8.08	.608	-.065	.080
	(3.07)	(3.50)			
Coherent story	9.05	9.46	.259	-.143	.201
	(2.86)	(3.07)			
Representations	90.03	86.75	.087	.219	.402
	(17.66)	(17.66)			

* = Significant at p <.05. ** = Significant at p <.01.

Note. The mean (standard deviation) score of participants' total score for each EFT phenomenology variable for each delay, along with the p-values for each variable and the associated effect size and statistical power.

Figure 3.8: The representation richness variable and the 5 individual variables.



Note. The 5 individual representation richness variables (autonoetic, sensory, spatial, temporal, and emotional) along with the representation richness composite variable, across the 2 delays (1 day, 1 year). All but the emotional variable decreased with increased delay. Note that this graph is for illustrative purposes only. The means have been transformed to show the change in valuation over time. See Table 3.11 for the actual means and standard deviations for each of the phenomenological measures.

3.5.3.3 TEMPORAL CONSTRUAL

Here participants' proportionate preference for low-level construal relative to high-level construals was measured. While participants showed a greater high-level construal preference overall, participants significantly preferred more low-level construals for short delays (M= .36, STD = .20) than they did for long delays (M = .29, STD = .17), $t(62) = -3.16$, $p = .002$, $d = .399$, confirming the hypothesis (H3c). The construal level measurement appeared consistent as correlations of preference ratings were .62 for the two delays, and the analysis was well-powered as per post-hoc power analysis ($n = 63$, $\alpha = .005$, $1 - \beta = .952$).

3.5.3.4 DELAY DISCOUNTING AND EPISODIC TAGS

Participants' proportion of larger-later choices relative to the total number of choices made was measured for each of the 4 conditions (dates or delays x tagged or untagged). Means and standard deviations can be found in Table 3.12 and Table 3.13. A mixed 2 x 2 ANOVA was carried out, with episodic tagging and delay-format as the independent variables. Results showed a significant main effect of episodic tagging on discount rates, $F(1, 61) = 31.45$, $p < .001$, $\eta_p^2 = .340$,in which episodic tags (66% LL-choices) led to less discounting than in the untagged condition (52% LL-choices). There was, however, no significant main effect of delay-format, $F(1, 61) = 0.28$, $p = .601$, $\eta_p^2 = .005$, as the effect appeared to be present in the standard non-tagged condition, but not in the tagged condition. There was a significant interaction effect between episodic tagging and delay format, where the episodic tag effect was different in the day-format and date-format conditions, $F(1, 61) = 8.54$, $p = .005$, $\eta_p^2 = .123$. This interaction effect confirmed the predictions (H2) and is illustrated in Figure 3.9.

Post-hoc power analyses showed that the ANOVA was both sufficiently powered to detect the main effect of episodic tagging ($n = 63$, $\alpha = .001$, $1 - \beta = .984$) as well as the interaction effect between episodic tagging and the delay-format ($n = 63$, $\alpha = .005$, $1 - \beta = .984$), but not for the main effect of delay-format ($n1 = 31$, $n2 = 32$, $\alpha = .005$, $1 - \beta = .086$).
Although, in the untagged condition, the day-format (47% LL-choices) did lead to more discounting than the date-format (58% LL-choices), as predicted by the date/delay effect, this did not reach significance with an independent-samples t-test, $t(61)$, = -1.67, $p = .100$, whereas there was no date/delay effect in the tagged condition (date-format: 65% LL-choices; day-format: 69% LL-choices), $t(61) = .73$, $p = .468$, $d = .184$. Post-hoc power analyses showed that neither the t-test for the untagged condition ($1 - \beta = .373$) nor the t-test for the tagged condition ($1 - \beta = .111$) were powered enough to show an effect of delay-format ($n1 = 31$, $n2 = 32$, $\alpha = .05$).

Table 3.12: Proportion of larger-later (LL) choices (i.e., discounting) per condition.

	Day-format		Date-format	
	Tagged	Untagged	Tagged	Untagged
Mean	**.69****	**.47****	**.65***	**.58***
St Dev	.22	.18	.28	.31
N	32	32	31	31

* = significantly different at p < .01, ** = significantly different at p < .001.

Note. In the untagged condition, there were more larger-later choices when delays were written as dates rather than days. The opposite was true in the tagged condition, but the difference between the amount of larger-later choices in day-format and date-format was much smaller.

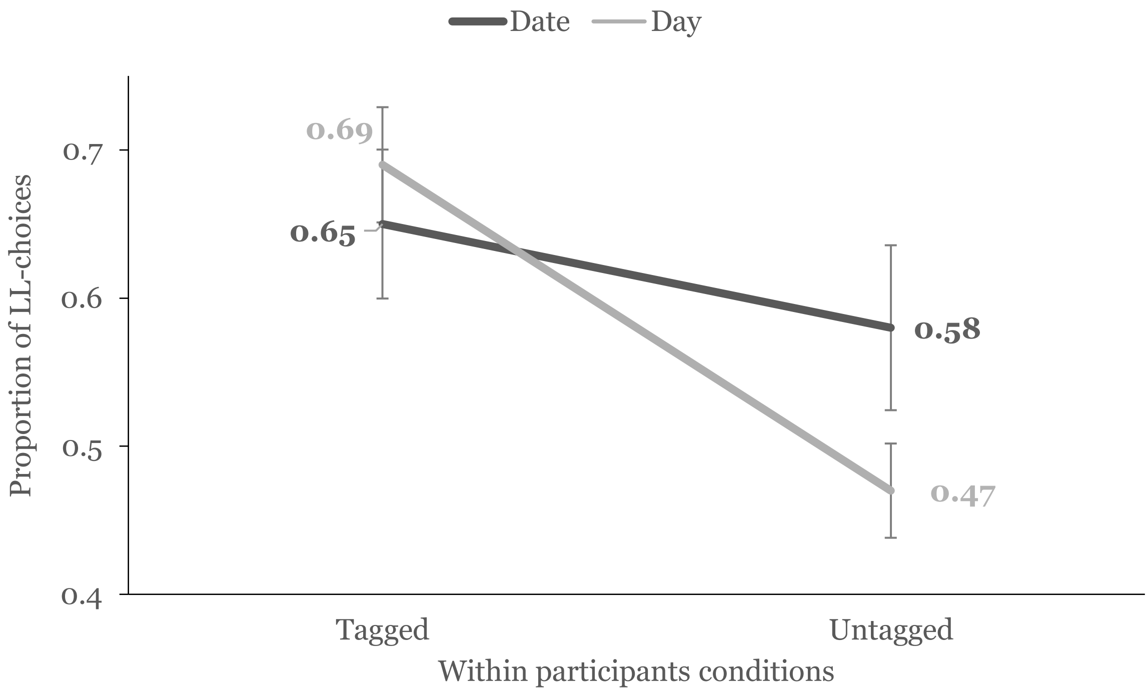
The data was split between date and delay to explore the effect of episodic tagging within each of these conditions, using paired-samples t-tests. Within the day-format condition there was a significant effect of episodic tagging, $t(31) = 4.99$, $p = .001$, $d = .882$, in which the episodically tagged condition (69% LL-choices) showed less discounting than in the untagged condition (47% LL-choices). Likewise, in the date-format condition, episodic tagging (65% LL-choices) led to less discounting than in the untagged condition (58% LL-choices), $t(30) = 2.67$, $p = .012$, $d = .479$. Both the t-tests for the day-format ($1 - \beta = 1$) and the date-format ($1 - \beta = .963$) were powered enough to detect the episodic tagging effect ($n = 63$, $\alpha = .05$) according to post-hoc power analyses.

Table 3.13: Proportion of larger-later (LL) choices (i.e., discounting) per variable.

	Day-format	Date-format	Tagged	Untagged
Mean	.58	.61	**.66***	**.52***
St Dev	.20	.16	.25	.25
N	32	31	63	63

* = significantly different at p < .001.

Figure 3.9: The interaction effect of episodic tagging and delay-format.



Note. The y-axis shows the proportion of larger-later choices as a measure of discounting. In the untagged condition, there were more larger-later choices when delays were written as dates rather than days. The opposite was true in the tagged condition, but the difference between the amount of larger-later choices in day-format and date-format was much smaller.

3.5.3.5 RELATIONSHIP AMONG THE CONSTRUCTS

Like Studies 1-2, the final part of Study 3 sought to examine the relationship between the constructs in terms of individual differences. Table 3.15 shows correlations between all the constructs looked at thus far: temporal discounting, construal level and EFT, of which only the correlation between preference for high-level construal and the EFT richness composite variable was significant, like Study 1, contrary to the predictions (H1c, H1a-b were also rejected).

Moreover, neither age nor gender correlated with any of the constructs of interest. Post-hoc power analyses revealed that only the correlation the tag effect and either discounting ($1 - \beta = .955$) or EFT richness ($1 - \beta = .907$) were powered sufficiently ($n = 63$, $\alpha = .05$). The correlations between high-level construal preference and either EFT richness ($1 - \beta = .740$) or the tag effect ($1 - \beta = .433$) were underpowered, and the correlations between discount rates and either EFT richness ($1 - \beta = .506$) or high-level construal ($1 - \beta = .358$) were the most underpowered.

Table 3.14: Means (St.dev) for all participants, per gender and age group.

		EFT Richness	Discounting	High-level construal	Tag effect	*N*
Gender						
	Female	180.28 (25.43)	-2.05 (.67)	.70 (.15)	3.22 (4.70)	40
	Male	170.70 (36.76)	-2.33 (.72)	.62 (.18)	2.39 (3.66)	23
Age						
	19-39	175.53 (30.60)	-.2.16 (.71)	.69 (.15)	3.18 (4.46)	57
	40-66	188.67 (24.20)	-.2.06 (.58)	.55 (.24)	.50 (1.87)	6
Total		176.78 (30.13)	-2.15 (.70)	.68 (.17)	2.92 (4.34)	63

Note. The bottom rows show the average EFT Richness score, Discounting rate log(k) and high-level construal preference across delays for all participants. The above rows show the averages score within female, male and ages 19-39 and 40-66. Higher EFT Richness score mean greater EFT richness, higher discount scores mean more discounting and higher high-level construal scores mean more high-level construal choices over low-level construals.

Table 3.15: Correlations among EFT, construal, discounting and tag effect.

	High-level construal	Discounting	Tag effect	Gender	Age
EFT Richness	**.29***	.05	.15	-.15	-.05
High-Level Construal	-	.04	.06	-.23	-.24
Discounting	-	-	.18	-.19	-.05
Tag effect	-	-	-	-.09	**-.26***

* = Significant at p <.05.

Note. Correlations among overall EFT, construal, discounting and magnitude of episodic tag effect across participants in Study 3, collapsing across delay for EFT and construal, and using log(k) for discounting. Each of the three variables of interest were collapsed across delay in order to produce one individual difference measure each, irrespective of delay.

3.5.4 DISCUSSION

The main finding of this study was the interaction effect between the delay-date effect and the episodic tagging effect. While there was no main effect of delay-format, the initial discounting part of this study successfully replicated the date/delay effect where people discount less when delays are written in calendar dates than in number of days (Read et al., 2005). The study also replicated the episodic tagging effect, as there was a main effect of episodic tagging, where people discount less when delays are accompanied with episodic tags that serve as a verbal reminder of what the person will be doing at that time (Peters & Büchel, 2010). When delays were accompanied with episodic tags, however, there was no added effect of having the delays written in a date format, demonstrating an interaction between delay-format and episodic tagging.

This study differed from Studies 1 and 2 by being carried out in the lab rather than online, and reducing the number of delays from 4 to 2, in order to retain power as fewer participants could be tested in the lab rather than online. The more closed-format construal level task of Study 1 was used, and the episodic tagging procedure of Study 2 was incorporated, as well as the date-delay format, in which some participants only saw delays in number of days whereas others were presented with specific calendar dates.

There was no main effect of delay-format upon discounting, and there was no significant effect of delay-format within the tagging condition, nor within the untagged condition. However, there was a trend towards more discounting in the untagged day condition compared to the untagged date condition. In the untagged condition there was more discounting in the day-format condition than the date-format condition, whereas the trend was in the opposite direction in the tagged condition, with more discounting in the date-format condition compared to the delay-format condition.

The absence of a significant main effect of delay-format, or a significant effect of delay-format in the untagged condition was due to the experiment not being powered enough to detect this effect, as revealed by the post-hoc power analysis. The between-subjects manipulation of the delay-variable meant that only 31-32 participants were in each condition, and the within-subjects tagging variable meant that there were only 20 trials for the tagged and untagged condition each. Having said that, Read et al. (2005) found the date/delay effect with 4 trials and 30 participants per condition. So perhaps the within-subject episodic tag introduced more noise due to its potential shared mental representations with the date/delay effect. Regardless, the purpose of this part of the experiment was to investigate if there were any interaction effects. Moreover, the design of the *initial discounting* part of the experiment was effectively the same as the *untagged* condition in which a significant delay-effect was found. Both the date/delay effect in the initial discounting task and the subsequent episodic tagging effect were well-powered to detect the large effect sizes.

Consistent with the previous two studies, there was a strong effect of delay on discounting, as valuation decreased with delay. Unlike the previous two studies, the effect of delay upon construal was successfully replicated. People were more likely to select high-level construal descriptions if activities were set to occur in the distant future, and more likely to select low-level construal descriptions if the activities were set in the near future.

The effect of delay upon the composite *representation richness* variable for EFT phenomenology was not significant, although there was a trend for less representation richness with increasing delay, consistent with Study 2 but not Study 1. However, there was a decrease in temporal context with delay, but not in sensory detail, consistent with Study 1 but not Study 2. Consistent with both Study 1 and 2, there was no effect of delay on autonoetic consciousness, emotional experience, use of words and coherent story.

Like Study 1 and 2, when comparing across 1 day to 1 year in the future, *emotional experience* was the only phenomenological EFT measure that went contrary to predictions, by increasing rather than decreasing with delay. Also consistent with Study 1 and 2, this increase with delay was not significant. Emotional experience decreased slightly from 1 day (5.23 in Study 1, 5.54 in Study 2) to 1 week (5.20 in Study 1, 5.46 in Study 2) before increasing slightly towards 1 month (5.24 in Study 1, 5.49 in Study 2) and then slightly more towards 1 year (5.37 in Study 1, 5.57 in Study 2).

While this erratic pattern of how delay affected emotional experience is likely due to noise, it may have a theoretical account. D'Argembeau and Van Der Linden (2006) found that individual differences in emotional experience (which they called 'feeling emotions') of episodic memories correlated with their emotional experience in episodic future thought. It could be that the sort of events participants chose to remember are those which still evoke great emotional experiences. For the near future people might be more likely to choose more mundane events, such as giving a lecture, taking the train or taking a test, whereas for the distant future they are more likely to choose more emotionally charged events like weddings, a PhD viva, or a holiday. These were all examples from this experiment.

Collapsing across the delays, discounting did not correlate with neither construal level nor EFT. However, there was a correlation between construal level and EFT richness, where those who scored higher in representation richness also chose more high-level construals. While this positive relationship came out significant in both Study 1 and 3, it was not in the predicted direction, as high-level construals are described as having *less* sensory, temporal, and contextual details whereas greater representation richness suggests *more* sensory, temporal and contextual details.

So far Study 1, 2 and 3 have all replicated the effect of discounting upon delay where people value options less with delay. Study 1, but not study 2 and 3, showed how representation richness decline with delay, and Study 3, but not study 1 and 2 showed an effect of delay upon construal levels where people choose more low-level construals for near-future activities and more high-level construals for distant future activities. Study 2 and 3 replicated the episodic tagging effect, and Study 3 replicated the date/delay effect, but demonstrated an interaction effect between episodic tagging and delay-format where a date-format does not further attenuate discounting when the delay is episodically tagged.

3.6 GENERAL DISCUSSION

The aim of these three studies was to explore the relationship between delay discounting, temporal construal and episodic future thinking (EFT). Study 2 and 3 also sought to examine how these representations might be related to phenomena like the date/delay effect and episodic tagging, both of which have been argued to be related to the ways in which the future is represented. Study 1 and 2 were run online with American participants, and 4 delays, whereas Study 3 was run in the lab, using only 2 delays.

Across all three studies, there was no significant relationship between overall delay discounting, construal level and EFT. That is, individual differences in time preference were not related to individual differences in EFT richness nor construal level preference. However, in Studies 1 and 3, more high-level construals was related to greater representation richness in EFT. Thus, the similarities between construal levels and EFT in phenomenological descriptions and descriptions may be explained by individual differences. That is, people who make more high-level construals are also more likely to have greater representation richness in EFT.

As for the individual measures, only Study 3 showed a significant effect of delay upon construal levels, where people made more low-level construals for the immediate future and more high-level construals for the distant future. And only in Study 1 was representation richness reduced with increasing delay. Spatial context was the only variable that decreased with delay in all three studies, and emotional valence and personal importance the only variable to increase with delay in all three studies.

Consistent with the initial discounting task in the aforementioned studies there was an effect of delay on valuation of rewards, as participants valued rewards less with increasing delay to receipt. Unlike Study 2, Study 3 successfully replicated the date/delay effect in the initial discounting task, in which participants discount less when the alternatives in the delay discounting task are written in specific calendar *dates* rather than number of *days*. Because this effect came out significant, it was explored whether the date/delay effect would have an additive or interactive effect with the episodic tagging effect.

The construal level component of Study 3, unlike Studies 1 and 2, showed a highly significant construal preference, where people preferred low-level construals for near-future activities and high-level construals for distant-future activities. The design of this component was largely the same as that of Study 1, but the delays were reduced from 4 to 2, and the number of trials for each delay were increased from 3 activities per delay to 20 activities per delay, to maximize power. While running the experiment in the lab rather than online may have been a contributing factor to reaching significance, the trend was in the predicted direction in Study 1, suggesting that a greater number of trials was what it took for sufficient power.

Lastly, there was an interaction effect between episodic tagging and delay-format in the final delay discounting task that displayed episodic tags for half the larger-later trials. There was a main effect of episodic tagging, and episodic tagging significantly led to lower levels of discounting within both the date-format and day-format conditions. The date/delay effect was larger in the untagged condition than the tagged condition (indeed it was numerically reversed in the latter). When a delay was episodically tagged, there was no further advantage of a date-format to reduce discounting. This interaction effect suggest that what drives the date/delay effect is the same that drives the episodic tagging effect.

None of the potential accounts for the date/delay effect posed by Read et al. (2005; see section 2.3.1.4) were specifically to do with EFT or mental representations more generally. However, the idea that date-framing makes people estimate the interval between delays differently, or that dates seem more similar to the decision maker than delays, are both compatible with a mental representation account. Read et al. (2005) suggested that date-framing may affect more than mere valuations, and the present findings suggest that it might affect mental representations in a similar manner to what episodic tagging does.

3.6.1 LIMITATIONS

A limitation to this explanation is that episodic tagging and the date/delay effects may not necessarily rely on the same underlying mental representations, but rather the attentional shift towards one may result in people not attending to the other. For instance, if a decision maker attends more to episodic tags at the expense of date-formats, one would not expect to see further attenuation of discounting from date-formats (relative to delay-formats) on top of the attenuation of discounting as a result from episodic tags (relative to no episodic tags). The similarity- and time estimation- accounts of the date/delay effect remain interesting however, as they best accounted for the results found by Read et al. (2005) and are compatible with an EFT account of mental representations.

A potential drawback of Study 1 and 2 is that they were both run online. There is never a guarantee that participants are fully paying attention to the tasks of the experiment, with no surrounding factors that could distract from engaging in EFT or form construal levels. For that reason, Study 3 was run in the lab, using the same measures as Study 2, except for the construal level measure of Study 1. It should however be noted that the construal level measures in these studies are not commonly used to measure individual differences, so they might not be suitable for that purpose. Nonetheless, there was an effect of delay upon construal in the lab-based study (Study 3), and individual scores on this measure correlated significantly with greater representation richness in EFT.

A minor criticism is the EFT phenomenology measure ‘coherent story’, which asked participants to what extent the imagined event comes to them as a coherent story rather than as an isolated scene. While this measure was retrieved from D’Argembeau and Van Der Linden (2006), Berntsen and Bohn (2010) found that 71% important future events referred to life script events (e.g., marriage, having children, retirement). But when events were word cued, this was only a minority of the events. This suggest word cues impacts whether such life script events are imagined. Because the present studies used word cues to elicit events, this may have been the reason why this measure did not significantly increase with delay.

Another criticism is that the three measures were looking at different *items*. Discounting and discounting using EFT tags and/or date/delay manipulations were all focused on monetary options. Meanwhile, the temporal construal task was focused on various activities, and EFT on specific events. This could explain why only EFT and construal level correlated in Study 1 and 3, but that there was no relationship between these and discounting. In order to eliminate this potential problem, a task might be devised so that people discount on, form construals on and generate episodic future thoughts on the same items.

Because all measures (discounting, construal, EFT and episodic tagging) involved delays there is the possibility that the one measure could be affected by the preceding measure. However, the research literature on discounting indicates there is little reason to believe there would be carry-over effects in terms of delay from one part of the experiment to another (Matthews, 2012; Alempaki et al., 2019). It is more difficult to rule out whether construal level measures impacted on EFT measures, but there is no reason to think it would have a directional effect as the delays in the construal level tasks were randomised within-participants.

3.6.2 IMPLICATIONS

If the episodic tagging effect and the date/delay effect are based on different mental representation of the future one would expect to see a main effect of each, and no interaction effect. The effects should then have been additive, where episodic tagging *in addition to* the date/delay effect would lead to less combination than each of the effects on their own. Instead, there was an interaction effect where there is a greater effect of episodic tagging upon discounting in the day-format condition than in the date-format condition. In the day-format, there is a 22% higher rate of discounting when larger-later options are tagged relative to untagged, whereas in the date-format, there is a 7% higher rate of discounting for tagged rather than untagged large-later options.

If the episodic-tag effect and date/delay effect were truly independent, one would expect these percentages to be more or less the same. Conversely, if the effects were entirely dependent, one would expect no difference between the tagged and untagged condition in the date-format. In other words, there would be no interaction effect if the episodic-tag effect and the date/delay effect were entirely independent. But there was significantly more discounting in the untagged date-format condition compared to the tagged date-format condition. This suggest that there is a considerable overlap between the mental processes involving the episodic tag-effect and the date/delay effect.

3.7 OVERALL CONCLUSION

The main purpose of these three studies was to explore whether the large unexplained variability in individual's discount rates can be explained by individual differences in episodic future thinking (EFT) or construal level tendency. Across the three studies, variability in discounting could be accounted for by neither EFT nor construal. Discount rates were not significantly related to less representation richness with delay, or with greater high-level construal preference with delay. Thus, while EFT and construal levels can, according to the literature, influence discounting, neither individual differences in either appear to be driving discount rates in standard intertemporal choice tasks.

The most noteworthy finding in Study 3 was the interaction effect between the date/delay effect and the episodic tagging-effect. In the literature, episodic tagging and delays written in a date-format have been found to reduce discounting, separately. If the effects were independent of one another one would expect to see an additive effect, but the interaction effect suggest that the two are at least in part caused by the same underlying mental representation of the future.

Read and colleagues (2005) proposed a number of potential explanations for the effect. Most relevant to the present findings, they hypothesised that the date-format reallocates attention from the duration of the delay to the moment of receiving the amount. Focusing more on the amount than the delay will thus make people more patient and discount less. But the results of study 3, where episodically tagging both options led to attenuated discounting, suggest that there is more than a mere attention shift going on. People appear to be mentally travelling in time.

Peters and Büchel (2010), whose episodic paradigm was adapted, argued that the episodic tagging effect could not be explained by what they called *date-based processing*, referring to the date/day effect of Read and colleagues (2005). As a measure of *temporal focus*, their participants rated whether they based their choices on the delays as displayed, or if they converted the delays to specific dates and made their decisions based on those. There was a significantly greater date-based processing in the episodically tagged condition relative to control. However, the researchers argued that the episodic tagging-effect was due to a difference in temporal focus, as the temporal focus ratings of each condition did not correlate.

The above findings together with the findings of the present study suggest some relationship between date-based processing and episodic tagging. If engaging in EFT via episodic tagging does not make people process delays as dates per se, then delays presented as dates appear to engage the same processes involved in episodic future thought. Considering that the *date/delay effect* was absent in the tagged condition of the present study, this suggests that episodic future thought was already prompted by the episodic tag, and that there was not much more to gain from encouraging *date-based processing*. In other words, date-based processing might be the same underlying processing as episodic future thinking. An alternative account which these results cannot rule out is that whatever mechanisms drives the episodic tagging effect and the date/delay effect, these mechanisms can only be used one at a time. For instance, if attending to the episodic tag makes the decision maker not attend to the date, and consequentially there is no added effect of the date format to the effect of the episodic tag.

3.7.1 DELAY DISCOUNTING

Across all three studies there was a clear effect of delay upon valuation, and the values of *k* were comparable for all three studies (0.006, 0.007, 0.009 days-1 for Study 1, 2 and 3 respectively). Thus, the time preference measures were reliable overall and consistent with the literature. The date/delay effect was not replicated in Study 2, but Study 3 showed a clear date/delay-effect. Study 3 had only 67 participants in the lab, compared to 150 online participants in Study 2. It is unlikely that the lack of effect was due to online participants not engaging with the task, as delay had a clear effect on their valuations. Thus, the reasons for this might be that Study 2 took place towards the end of the year, whereas Study 3 was carried out early in the year. Thus, dates described in a coming year (i.e., year 2020 when it is still year 2019) might feel further away in November than the same temporal distance when it is April. There is some evidence to suggest that people use temporal landmarks, such as birthdays, to mentally organise their lives and add structure to their perception of time (Peets & Wilson, 2013). These temporal landmarks, in turn, make people feel less connected and similar to their future post-landmark selves. Given this, it is possible that people in the present study felt less connected to their future selves after the landmark of the new year, and that this made them discount more. This also fits with Hershfield and colleagues' (Hershfield et al., 2011: Ersner-Hershfield et al., 2009), research on how people's sense of their future selves' impact upon their discounting (see section 3.1.4.1.1).

3.7.2 CONSTRUAL LEVEL

The effect of delay upon construal was variable across the three studies. The effect was bordering on significant in Study 1, but not significant in Study 2. However, when substantially increasing power in Study 3, a clear effect of delay upon construal was observed. Study 2 lost power from all the participant-generated descriptions that could not be coded as either high- or low-level construals, so it appears that an experiment needs substantial power in order to find an effect of delay upon construal level preference. The difficulties of finding an effect of delay on construal is concerning as we used measures from the methods which laid the foundation of the theory. As discussed in the literature review (section 3.2) the theory is slippery and appears to be rather context dependent in the senses that it can be interpreted in different ways depending on context. So, the measures used in these studies might be sensitive to how they are implemented (i.e., online versus in the lab) or to what culture the participants belong to. In the literature this has led to contrary findings, which the theory could be used to explain post-hoc either way, so this does tie in with the more inherent problems with construal level theory as a whole.

3.7.3 EPISODIC FUTURE THINKING

The phenomenological measures of EFT declined (autonoetic consciousness, sensory representations, spatial context, temporal context) or increased (emotional valence, personal importance, use of words, coherent story) as predicted. The only exception to this was *emotional experience*, which was predicted to decrease with delay but instead seemed to remain fairly similar for all delays.

There was a significant effect of delay upon spatial context, emotional valence and personal importance across all three studies, whereas temporal context only significantly declined in two studies, and sensory representations in only one. Overall, the composite measure of autonoetic consciousness, sensory representations, spatial context, temporal context and emotional experience; representation richness only showed a significant effect of delay in Study 1. The difficulty in correlating these individual differences in EFT to individual's discount rates could therefore be down to the weak effect of delay on the EFT measurement in the first place.

If the effect of delay upon representation richness had been significant for all three studies, and all three studies *still* showed no relationship between EFT representation richness and discounting, one could with greater confidence say that individual differences in EFT and discounting are not related. However, not being able to show a significant effect of delay upon EFT representation richness still leaves the possibility that the failure to replicate this effect was the reason the two measures did not map onto each other.

3.7.4 EPISODIC TAGGING

This strand of research managed to successfully replicate the episodic tagging effect in both Study 2 and Study 3, demonstrating that while there was no relationship between individual differences in EFT and discounting, engaging in EFT significantly reduces discounting. Moreover, the Peters and Büchel (2010) paradigm was successfully adapted to suit an online study. The original design was based on interviewing participants about their personal future plans, and the researchers using these plans to generate episodic tags. These experiments made this process more efficient by having participants come up with events and tags themselves. This adapted paradigm would be useful for future online research that seeks to explore the episodic tagging effect.

3.7.5 CONCLUSION

In summary, the effect of delay upon discounting was consistent across studies, but the effect of delay upon construal and EFT was less consistent. Overall, construal and EFT did not explain the vast variability in individuals' discount rates, although there might be some shared commonalities between construal level and EFT. The key findings can be summarised as follows:

- There was no relationship between individual differences in EFT and discounting.
- Participants engaging in EFT through episodic tagging showed reduced discounting.
- Delays written in a date-format rather than a day-format led to lower discount rates.
- There was no additive effect of date-format and episodic tagging, suggesting that the mental processes involved in the episodic tagging effect might be shared with those involved in the date/delay effect.

Thus, while people discount less when engaging in EFT, individual differences in EFT and individual differences in discount rates are not related. This is consistent with existing research on amnesic patients that show how EFT is not necessary for normal discounting (Kwan et al., 2012) but that engaging in EFT by mentally time travelling to the moment of receipt can reduce discounting when prompted to (Peters & Büchel, 2010; Benoit, Gilbert & Burgess, 2011), but not for amnesic people (Palombo, Keane & Verfaellie, 2015). That is, people may not spontaneously engage in EFT, nor are required to engage in EFT to show normal discount rates.

This study sought to explain these findings by exploring the relationship between individual's discount rates and individual differences in EFT. If people who discounted less also showed more representation richness when engaging in EFT, this could account for lower discount rates. However, it does not appear that individual differences in EFT can explain the large unaccounted for variability in discounting behaviour.

While not able to explain individual discounting variability with individual differences in EFT nor individual differences in temporal construal, this strand of research demonstrated a relationship between temporal construal, EFT and the date/delay effect. People who form more high-level construal have greater representation richness when engaging in EFT. Moreover, while engaging in EFT reduces discounting and date-formats reduce discounting, there is no additive effect of the two, suggesting they might share an underlying mechanism.

4 PROCESS TRACING WITH EYE TRACKING

So far, this thesis has been focused on how mental representations of the future are related to intertemporal choice. The studies in this chapter seek to explore how these mental representations of the future are *processed* in order to make a decision. To reiterate, mental processes refer to how external reality is symbolised in the mind, whereas mental processes describe what we do with these mental representations. Here, the aim is to explore the mental representations of the actual choice context. This strand of research focuses on what people are choosing to look at and in what order, as a proxy of what they are attending to, rather than whether their gaze determines their choice. Because of this, eye tracking technology was employed to directly measure what people are fixating on when discounting.

Theories of decision making have largely focused on developing models that explain and predict what choices and judgements people make. However, this approach is only able to make inferences based on the choice context and the actual choice or judgement made, rather than the process that led up to the final outcome. A variety of methods have been employed in order to trace the mental processes that take place between this input and output, such as verbal protocols and information search displays. However, eye tracking offers the unique opportunity to trace what people look at, to infer what they attend to, without any potential distractions in having to declare or manually reveal the items they are looking at.

What people look at can reveal what comparisons people make when making intertemporal choices. Whether they are making transitions within attributes or within options have implications for whether discounting or trade-off models are appropriate models of the choice between smaller-sooner and larger-later rewards. The aim is less to model how cognition works and how people make decisions, but more about how people choose to look at things to get a sense of what they are weighing and comparing. Thus the key focus of these experiments is people's information search when making intertemporal choices.

4.1 EYE TRACKING LITERATURE

This literature review covers the early use of eye tracking technology as well as the role of other process tracing methods in the JDM literature. Eye-tracking specifically has demonstrated the role of gaze in choice formation more broadly, and more specifically in intertemporal choice as well. Although the research of this thesis is only concerned with theories involving time, the literature covers examples from the adjacent research area of risky choice. This area has notable examples of how process tracing technology such as eye tracking and other methods can test predictions from models of risky choice. Much like models of intertemporal choice, models of risky choice can be classed as either option-based or attribute-based (discussed in section 2.2.2 and in the upcoming section 4.1.4). Given how the predictions of these have been successfully tested with process tracing methods for decisions involving risk, this should also be possible for decisions involving time.

4.1.1 EYE TRACKING HISTORY

Eye tracking provides invaluable insight into how people mentally process visual information, as it indicates what visual information people overtly attend to. Ever since the pioneering work of Alfred Yarbus (1967) demonstrated the link between eye movements and cognitive processes, numerous studies have emerged, supporting this relationship (Kowler, 1991; Henderson, 2003). Eye movements can be a window to processing and processing can in turn be used to predict eye movements (for reviews, see Hayhoe & Ballard, 2005; Liversedge & Findlay, 2000). For instance, eye tracking has shown how syntax in language processing influences eye movements when reading (Rayner, Carlson, & Frazier, 1983) and this study led to a steep increase in eye tracking studies on reading research the following decade. Examples of this and other studies of eye tracking in researching mental processes follow below.

When eye tracking is used to investigate how people read, researchers often compare the eye movements from reading ambiguous and comparable unambiguous sentences. In a study by Duffy and Rayner (1990), participants read a paragraph with a category noun (e.g., *bird*) preceded an either typical (e.g. *robin*) or atypical (e.g. *ostrich*) exemplar of that category. Reading times were shorter when the exemplar was typical and closer (i.e. fewer words between exemplar and category) for that category, showing how gaze duration is guided by semantic comprehension. People had to look for longer at the category noun when the exemplar was atypical, in order to disambiguate the paragraph.

Beyond language processing in reading, eye tracking has provided insight into the cognitive processes underlying how people carry out daily activities, such as preparing tea (Land, Mennie, & Rusted, 1999), walking (Jovancevic-Misic & Hayhoe, 2009) and driving (Land & Lee, 1994; Shinoda, Hayhoe & Shrivastava, 2001). In recent years, eye tracking devices have become more affordable, and allow for the participant to move more freely. Thus, researchers can with greater ease measure eye movements in a non-invasive manner, while participants unrestrictedly take in the relevant information without any need to engage with the measurement of this process.

Because eye tracking can directly measure overt attention via eye movements, researchers have successfully used it to explore attentional biases towards emotional stimuli in people with depression or anxiety (Armstrong & Olatunji, 2012). A meta-analysis compared individuals with anxiety and individuals with depression to healthy controls. Results showed an attentional bias towards threatening information in individuals with anxiety, but not depression. In free viewing tasks anxious individuals fixated on threatening stimuli more, and in visual search tasks they showed greater detection of threatening information. Meanwhile, in free viewing tasks, individuals with depression fixated less on positive stimuli than controls, and their fixation durations were shorter for positive stimuli, and longer for dysphoric stimuli. Overall, the results showed how attentional biases, as indicated by eye movements, where people attend to more to information that increase depression and anxiety, and less to information that has the potential of reducing depression.

Eye tracking technology has also been used to challenge the traditional social learning idea that aggressive children are more attentive to hostility in others' behaviour (Horsley, de

Castro & Van der Schoot, 2010). The eye movements of 10-13 year old children with high levels of aggressive behaviours were compared with 10-13 year-olds with low levels of aggressive behaviour, while they watched cartoons depicting ambiguous provocation situations. As indicated by eye movements, the aggressive children neither attended more to hostile cues nor less to non-hostile cues. They did, however, show longer fixation durations for non-hostile cues despite attributing more hostile intentions overall in a subsequent interview. Thus, eye tracking technology, along with verbal reports, presented evidence contradicting traditional explanations for aggressive behaviour, in which aggressive children are less attentive to non-hostile cues. Instead it appears that children attend non-hostile cues more, but do not process or remember these, as evident in how they subsequently attribute hostile intents more that do not take into account non-hostile information.

The above two studies are just two of many examples where eye tracking technology has informed what people overtly attend to, and how this is related to their cognitions. More relevant for this chapter, eye tracking has been used to inform researchers about what people attend to in judgement and decision making tasks.

4.1.2 PROCESS TRACING IN JUDGEMENT AND DECISION MAKING

Because of the reduced costs and invasiveness of eye tracking in recent years, there has been a rapid increase in the use of this technology in the context of decision making (see Glaholt & Reingold, 2011; Ashby et al., 2016). Searching Google Scholar with the terms "eye tracking" and "decision making" yields 846 results for the years 1980-2000, compared to 20.6k results for the years 2001-2020. Compared to just searching for "decision making" which yields 1,580k and 1,140k results for the same time periods, respectively, it is evident that eye tracking has become an important tool to trace the information uptake during judgement and decision making.

Researchers have however been attempting to trace mental processes for longer than the widespread use of eye tracking in judgement and decision making. The earliest studies used *verbal protocols*, which simply had participants verbally declare their reasoning and actions

(Glaholt & Reinhold, 2011). Although useful in revealing the order in which people sample information and what decision strategy they employ, this methodology has its problems. Having to verbalise the decision making process whilst simultaneously making the decision has been shown to reduce decision accuracy, and having to declare the decision making process in retrospect show considerable forgetting and confabulation (Russo, Johnson & Stephens, 1989).

Before eye tracking, the go-to method for process tracing in decision making was *information search displays* (Ball, 1997; Billings & Marcus, 1983; Levin, Huneke & Jasper, 2000; Payne, 1976; Payne, Bettman & Johnson, 1993). The options along with their attributes are presented to participants in rows and columns, and all are concealed, except the one cell the participant chooses to reveal one at a time. This is what allows researchers to trace their processing, by tracing what participants choose to view, and in what order.

A well-known computerised version of this paradigm is *Mouselab* (Johnson et al., 1989; Payne, Bettman & Johnson, 1988), in which allows participants to reveal attributes with ease by hovering a mouse over the cells they wish to view. This allows researchers to identify which attributes are being looked at, in what order and for how long. One example of a study that used Mouselab is that of Johnson and colleagues (2008) where they studied decisions involving risk and the predictions from prospect theory (Kahneman & Tversky, 1979) and the priority heuristic (Brandstätter, Gigerenzer & Hertwig, 2006). The priority heuristic describes how people follow a series of specific sequences of comparisons that people use to acquire information and make a decision; a so-called *three-reason stopping rule*. Hence, in a choice between two values at different probabilities, this would predict comparisons, as reflected by mouse transitions, between similar outcomes and similar probabilities.

Contrary to the Priority Heuristic and consistent with Prospect Theory, people made more comparisons between probabilities and values *within* each option. That is, they used their mouse to uncover attributes within a particular option in sequence more than they did between similar probabilities and similar values *across* options. This study demonstrates the value of process tracing. While the Priority Heuristic could, judging by input (values and probabilities) judge the output (choices made), the predicted underlying process was not confirmed by the process tracing technology. In this case, Mouselab revealed a pattern more consistent with traditional integration models like Prospect Theory, that people mentally represent a subjective value based on the value and probability of each option.

While Mouselab is more convenient than having to verbalise or recount the decision making process, it has some recognised shortcomings as participants are required to make deliberate physical actions to view the concealed information. Whereas in the real-world people simply direct their gaze, which is faster than hand movements and need substantially less deliberate effort. Numerous studies have shown how information search displays interfere with information uptake when participants have to actively uncover the information (Franco-Watkins & Johnson, 2011; Glöckner & Betsch, 2008; Lohse & Johnson, 1996).

Compared to eye tracking technology, Mouselab led to numerous discrepancies, most notably longer decision making times, more systematic information acquisition and less accuracy (Lohse & Johnson, 1996). And the discrepancies were greater when the task was more complex due to more options or more attributes. The main difference between eye tracking and Mouselab is that people have to deliberately reveal attributes in the matrix, and the above findings suggest that this is putting substantial demands on working memory. Consequentially, we may end up underestimating people's cognitive abilities. Hence, eye tracking technologies come out more favourably as it does not put the same demands on working memory and participants' only task is to make judgements and decisions. Even though Mouselab has its' known limitations, it is still however widely used as it is more affordable and possible to implement in online studies.

4.1.3 EYE TRACKING IN JUDGEMENT AND DECISION MAKING

The use of eye tracking in judgement and decision-making research has allowed researchers to more closely assess what visual information people attend to, and in what order and for how long. This gives a window in potential mechanisms behind the decision-making process.

Traditionally, JDM research has concerned itself with comparing the predictions of various theories with behavioural choice data. While this has been useful for predicting behaviour, it provides little insight into the underlying cognitive behaviours of such behaviour. With eye tracking, we can identify the different stages of the decision-making process, such as decision-making strategy changes and preference construction.

An early innovator in using eye tracking methods to track and identify people's decision-making process was Russo and colleagues (Russo, 1978; Russo & Dosher, 1983; Russo & Leclerc, 1994; Russo & Rosen, 1975). In one study Russo and Rosen (1975) had participants choose 1 out of 6 cars, that each had 3 attributes, which were displayed on screen while participants' eye movements were measured. This revealed that people were making pairwise comparisons, as their gaze moved back and forth between 2 of these cars. In particular, these comparisons tended to be made between the more similar cars which shared more attributes, and the cars that had been rated higher by the participant. In this study, eye tracking technology gave the researchers the unique insight that revealed how decision makers narrow down multi-alternative decision tasks to smaller sets of alternatives.

Eye tracking studies on choice preference has revealed biases in our gaze that predict choice preference. Pieters and Warlop (1999) had participants choose between a concurrently displayed array of six unique brands of the same product group (e.g., shampoo), while measuring their eye movements. They found that that the chosen items were fixated on more often and for longer durations. Thus, there appears to be a relationship between fixation duration and choice preference.

One determinant of preference in decision making tasks is *the Gaze Cascade effect*, which is a bias in looking behaviour when choosing between two options (Shimojo, Simion, Shimojo, & Scheier, 2003; Simion & Shimojo, 2006, 2007). When choosing between two options, people's gaze become increasingly biased towards the stimulus they eventually choose. This effect was first discovered by Shimojo and colleagues (2003) who presented pairs of faces on a screen and asked participants to choose which face they found more attractive. The researchers measured used eye tracking to measure participants' gaze while making these choices. While initially equally distributed between the faces, their gaze became increasingly more biased towards the face they eventually chose as the most attractive in the lead up to their choice. This positive feedback loop was also present in a similar task that used abstract shapes instead of faces, so it appears that gaze is an active part of forming preference.

The findings suggest that gaze has an active role in forming preference. The researchers further ruled out that this was solely due to a *selection bias*, which make people look more at their choice, and *memorisation of choice*, which is when people use their gaze to memorise their choice before responding. When participants judged which face was rounder, the effect was much weaker. That is, when making choices that was not directly to do with what they preferred, they did not show the same progressive gaze bias towards the chosen alternative. The authors argued that the role of gaze in preference formation is contributed by the integrated input of both cognitive processes comparing the options and their attributes, as well as gaze. On one hand, gaze biases the decision maker to attend to one attribute more, and on the other hand preference biases the decision maker's gaze, resulting in a positive feedback loop that reinforces the perceived attractiveness of an option.

There are two components to that interact to produce the *gaze cascade effect*. First, *the mere exposure effect* is when merely fixating at a stimulus leads to greater preference for that stimulus (Kunst-Wilson & Zajonc, 1980; Moreland & Zajonc, 1977, 1982; Zajonc, 1968). Second, *preferential looking* is when an individual fixates at stimulus they prefer for longer (Birch, Shimojo, & Held, 1985; Fantz, 1964). The gaze bias in preference decisions is a combination of the mere exposure effect and preferential looking, creating a positive feedback loop which leads to individuals eventually responding by choosing that stimuli (Shimojo et al., 2003). In sum, an individual's gaze is actively involved in the construction of preference. More JDM research using eye tracking will be covered in upcoming sections when discussing how eye tracking has been used to investigate within-option and within-attribute comparisons.

4.1.3.1 EYE TRACKING IN INTERTEMPORAL CHOICE

There has been little use of eye tracking technology in intertemporal choice, however Franco-Watkins, Mattson and Jackson (2016) measured decision makers' eye movements while they carried out conventional delay discounting tasks framed either as gains or losses (see section 2.1.3.1. for the gain-loss asymmetry). Both frames had trials consisting of a smaller-sooner option vs. a larger-later option, and in the gain-frame the outcomes were gains, whereas in the loss-frame the outcomes were losses. Immediate amounts ranged from $20-$80 for the delayed amount of $100 (*$100 trials*), and from $200-$800 for the delayed amount of $1000 *($1000 trials*). Delays ranged from 1 month to 10 years. Half the participants were presented with the gain-frame discounting trials first, and the other half the loss-frame discount trials first. They replicated the gain-loss asymmetry where in a gain-frame, people discount the later gain, as they prefer a good sooner rather than later, whereas in the loss-frame people discount the present loss as they would rather incur losses later than sooner, and that the discounting of losses is steeper than the discounting of gains.

Visually, there were 4 areas of interest (AOI, referring to specific regions on the display), presenting delays on top and amounts at the bottom, with the immediate option first. Number of fixations and fixation durations were measured for each of these AOIs, as were the proportion of time participants fixated on the AOIs (*AOI acquisition*), and the proportion of time participants revisited AOIs (*AOI reacquisition*). The researchers found differences between the gain-frame and loss-frame: There was a greater proportion of AOI acquisition in the gain-frame than in the loss-frame, and an interaction effect between frame and amounts for AOI reacquisition; In the gain-frame there were slightly fewer AOI acquisitions $1000 trails than in $100 trials. But in the loss-frame there were slightly more AOI reacquisitions for the $1000 trials than the $100 trials.

As for fixation durations, people fixated longer on delays in the loss-frames than in the gain-frames, and in the gain-frame trials, fixation durations were shorter for the shortest delay of 1 month than the other longer delays. However, in the loss-frame fixation durations were fairly consistent across delays. Thus, it appears that the gain- and loss-framing result in different eye movements that suggest differences in underlying processing.

More relevant to this chapter, the researchers explored the relationship between eye movements and choice. They measured *selection bias* by taking the sum of fixations on the smaller-sooner attributes minus the sum of fixations on the larger-later attributes, and dividing this by the total number of fixations. Thus, someone with a negative score show a fixation bias towards the larger-later option and someone with a positive score is biased towards the smaller-sooner option. For both delayed amounts and both frames, selection bias scores predicted choice. The more an individual looked at the immediate option, the more likely they were to choose that option, and selection bias scores were significant predictors of for both tasks and delays. Finally, selection bias scores predicted self-reported measures on risk taking, impulsivity and self-control better than discount values did.

The above findings highlight how employing eye tracking technology can give new insight to intertemporal choice. Specifically eye movements can predict what people will choose, and may have greater correlational validity to other constructs than the more conventional measures of individual discount values. The two studies of this chapter will also track eye movements as participants complete conventional delay discounting tasks, in a gain-frame only. However, the purpose of this study is to give a descriptive account of eye movements, as a reflection of mental representations, and to explore whether people represent options holistically or whether they compare each attribute across options.

4.1.4 EYE TRACKING AND OPTION/ATTRIBUTE COMPARISONS

So far this literature review has covered the early history of eye tracking technology as well as other process tracing methods employed in judgement and decision-making research. Continuing from the previous section which covered examples of how models of risky choice make predictions that can be tested with process tracing, this section explores how this has been done with eye-tracking.

Although the focus of this thesis is models of intertemporal choice, models of risky choice have in common that they can largely be classed as either *option-based* or *attribute-based*. These theories make testable predictions on what comparisons people make, which has been observed using eye tracking during risky choice. Thus, eye-tracking studies on models of risky choice illuminates how this technology can be used to compare option- and attribute-based models of intertemporal choice as well.

As described earlier, the pioneering work by Russo and colleagues explored what comparisons people make (Russo, 1978; Russo & Dosher, 1983; Russo & Leclerc, 1994; Russo & Rosen, 1975), and a wealth of research have used eye tracking to explore what information people fixate on as a measure of what they attend to (Day, Lin, Huang, & Chuang, 2009; Lohse & Johnson, 1996; Pieters & Warlop, 1999; Reisen, Hoffrage & Mast, 2008; Rosen & Rosenkoetter, 1976; Russo & Dosher, 1983; Selart, Kuvaas, Boe, & Takemura, 2006). Eye tracking has been used to explore whether people make more option-based or attribute-based gaze transitions (Payne; 1976; Payne et al., 1993; Glaholt & Reingold, 2011).

Option-based transitions means people shift their gaze from one attribute to a different attribute within the same option (within-option transitions), whereas attribute-based transitions are when people's gaze shifts from the attribute of one option to the same attribute of a different option (within-attribute transitions), respectively. For instance, someone looking for an apartment might use option-based comparisons by holistically comparing one apartment to the other. In a choice matrix, this might be reflected in people's eye movements moving from apartment to apartment. On the other hand, they might use attribute-based comparisons, comparing the rent of one apartment to the rent of the other, or the location of each of the apartments. Hence, in a choice matrix, eye movements should dart between from rent to rent, and from location to location.

These different information search patterns can reveal two different decision strategies, as more complex choice tasks often lead to a shift from option-based to attribute-based transitions. This results from decision maker's limited processing capacities that make it hard to generate a holistic mental representation of each option. Thus, they turn to a simpler heuristics-based approach where people make different comparisons, such as comparing along attributes instead of within options, or attend to some attributes more or less than others (Payne et al, 1993).

To recount the distinction between option-based and attribute-based models from section 2.2, decision making models have traditionally been *option-based*, sometimes also referred to as *alternative-based*. This is the idea that people mentally calculate a subjective expected value based on the option's attributes. Both Discounted Utility Model (Samuelson, 1937) and Hyperbolic discounting (Loewenstein & Prelec, 1992) are based on the idea that decision makers weigh outcomes by their respective delays. Similarly, in decision involving risk, both Expected Utility Theory and Prospect Theory (Kahneman & Tversky, 1979) hold that decision makers weigh outcomes by their probabilities by multiplying probabilities by amounts. Thus, people form a holistic mental representation of each outcome by considering the attributes of the given option.

Such holistic mental representations would predict that people look more *within* options as they weigh the attributes against one another. When using eye tracking technology to trace people's gaze, these option-based models predict that their eye movements should dart back and forth between the option's attributes more than between the options. Conversely, *attribute-based* models predict that people make attribute-based comparisons, which should be reflected in within-attribute transitions made across options. That is, people should be comparing the attribute of one option with the comparable attribute of the other option (e.g., "$3 in option 1 vs. $6 in option 2"), and this manifests as fixations transitions darting back and forth across options.

To reiterate: the two JDM research areas of risky choice and intertemporal choice have in common that they each have models that can be classed as either *option-based* or *attribute-based* models. There are numerous attribute-based models on risky choice that describe how people use simple heuristics to make comparisons within attributes, across options. One notable example of such attribute-based models is the priority heuristic which describe how decisions makers make comparisons in a particular order (Brandstätter et al., 2006). They first look at minimum outcomes, then the probability of that outcome and then they turn to the maximum outcome. There are also a number of attribute-based models for delay discounting, such as the trade-off model (see section 2.2.4). This model is entirely attribute-based, describing how people compare delays across options, and attribute across options.

With the assumption that eye tracking is a valid proxy for attention and processing (see section 4.1.5), this should be reflected in fixation transitions from one delay to the other, and from one amount to the other, across options. The following section covers examples form the literature risky choice showing how eye-tracking methods can be used to compare attribute- and option-based models of risky choice. More relevant for this thesis, this highlights how eye-tracking could be utilised in exploring attribute- and option-based models of intertemporal choice.

4.1.4.1 RISKY CHOICE AND OPTION/ATTRIBUTE-BASED MODELS

The aforementioned within-attribute vs. within-option gaze transition predictions have helped researchers in risky choice evaluate whether decision makers make more within-attribute or within-option transitions, respectively. More broadly speaking, if people form more holistic mental representations of the alternatives, or if they, due to information processing limitations, opt for a more heuristic based strategy in which they make comparisons across attributes (Payne et al., 1993). The former would present as *within-option gaze transitions*, and the latter as *within-attribute transitions*.

One example of such a study is that of Arieli, Ben-Ami and Rubinstein (2011) who had participants choose between high-probability-low-gain and low-probability-high-gain lotteries while recorded by an eye tracker. Participants' eye movements suggested that they were comparing gains and probabilities independently, which runs counter to traditional economic theory. Instead of making comparisons between holistic options, participants compared the options across each attribute. This suggest that they were using a more heuristics based strategy to compare along attributes, across options.

Glöckner and colleagues also tracked people's eye movements during risky choice in order to test the predictions made by several decision making theories (Glöckner & Herbold, 2011; Fiedler & Glöckner, 2012). In both studies they tracked decision makers' eye movements and pupil dilation during choices between gambles and found that participants looked more within gambles than between gambles. That is, people mad more holistic mental representations of each option than using heuristics to compare across options, within attributes. Together with the study by Ariely and colleagues (2011) this suggest people make both within-attribute and within-option based transitions. Looking across studies on risky choice that compare within-option and within-attribute transitions, the proportion of within-option transitions vary between 50% to 80% (Ariely et al., 2011; Fiedler & Glöckner, 2012; Glöckner & Herbold, 2011; Rosen & Rosenkoetter, 1976; Russo & Dosher, 1983; Su et al., 2013).

Stewart, Hermens and Matthews (2016a) sought to give an exhaustive exploration of eye movements in risky choice by building a statistical model of the frequency of various types of eye movements and how they are related to choice. Participants completed a series of choices between pairs of gambles while their eye movements were monitored. Visually, the two attributes (probabilities and outcomes) of each option was displayed on an otherwise blank screen. Options were either aligned vertically (left and right) or horizontally (top and bottom), and probabilities were either displayed first (left or top) or second (right or bottom). This was counterbalanced between participants in a 2 x 2 design so that one participant would always experience the same layout. The order of the two options was randomised on a trial-to-trial basis.

First the researchers explored the frequency of different eye movements and how often people fixated on these eye movements, e.g., probabilities versus amounts, or how many within-option versus within-attribute transitions people made. Results indicated that people made rather simple eye movements during risky choice. People fixated for about the same durations for the four on-screen attributes and this did not depend on what these were numerically. The only exception to this was that people made more fixations when choosing between gambles of similar probability, and the gaze cascade effect where people looked progressively more at the attributes of the option they would ultimately choose.

Moreover, the fixation durations per trial were very brief. Glöckner and Herbold (2011) and Fiedler and Glöckner (2012) also found very brief fixation durations in their studies. However, the gambles in Stewart et al. (2016a) were less complex, with 4 rather than 8 numbers on screen, and this was likely why decisions were even made more quickly. Such brief durations run counter to the predictions by option-based models like Expected Utility and Prospect Theory, as these predict people multiply probabilities and amounts, which should take people longer. Consistent with these option-based models, however: People made more within-option transitions than they did within-attribute transitions. That is, people looked more within each option, gaze darting back and forth between the probability and outcome of that option, compared to how frequently they looked between the options, comparing one probability to the other probability, and one outcome to the other outcome.

When exploring whether eye movements predicted the choices people ultimately made, people fixated more on the options they ended up choosing, independently of what the numerical values of the attributes were. Attributes have traditionally been the most used predictor of choice in judgement and decision-making research (Payne et al., 1993, Ashby et al., 2016). However, the amount of choice behaviour explained by attribute values only partially overlapped with the amount of choice variance explained by eye movements. Thus, while eye movements can only predict some of the variability in choice, this is for the most part not shared with the variance explained by attribute values, and so eye movements can predicts aspects of risky choice that have rarely been explored.

Overall, studies from decision under risk serve as a parallel to the potential in decision involving time. Eye tracking has been used to explore for how long and how much people look at the outcomes and probabilities of each option, and whether people look more within these options or between them. In the same manner it should be possible to trace eye movements on intertemporal choice, by having simple delay discounting tasks where people choose between smaller-sooner and larger-later options.

4.1.5 EYE TRACKING CAVEATS

So far, advantages of eye tracking have been outlined, along with interesting and relevant findings in the area of judgement and decision making. However, there are a few caveats to be mindful of when it comes to employing eye tracking technology. First, eye tracking inherently offers many degrees of freedom, as it is up to the researcher to define what makes a fixation and what makes a transition. It is therefore crucial that these are defined prior to analysis, once and for all, and not altered later on until the desired effect or prediction was found.

Moreover, while eye tracking is, as has been shown above, often used to explore underlying cognitive processes in choice, it is worth noting that information search is only a proxy for mental processing. While gaze generally reflects mental processing, it does not always map perfectly onto what someone is processing. People may be thinking about something different than what they are looking at, or remember something not in the search field at all (Orquin, Bagger & Mueller Loose, 2013; Towal et al. 2013; Turatto & Galfano, 2000).

People do not always look directly at what they are processing, as they may be covertly attending so something outside of what their gaze is fixated on (Posner, Snyder & Davidson, 1980). Likewise, people may not be making eye movements that reflect what comparisons they are making. For instance, people may only need to look at options along an attribute once and then go on to make comparisons along this attribute mentally, without this being reflected in darting repeatedly from option to option. However, there is no known reason to think that this would affect a relatively simple decision making task in a systematic way. The relationship between eye movements and the parts of the brain involved in attention is supported by neuropsychological studies (e.g., Goldberg & Wurtz, 1972; Kustov & Robinson, 1996; Mohler & Wurtz, 1976; Wurtz & Mohler, 1976). So, we can generally assume that eye movements provide a valid proxy of visual attention and thus mental processing.

4.2 CURRENT APPROACH

Eye tracking has been increasingly used to trace mental processing in judgement and decision making research. It has been used to describe choice strategies, to predict choice and to model decision making. The aim of this chapter is to explore what transitions people make between choice options, with reference to the mental representations and how changed mental representation may in turn qualitatively change what sort of transitions people make. Traditional discounting models make different predictions of what comparisons people make to that of tradeoff models, and these studies measure transitions as a proxy of these comparisons.

As outlined in chapter 2 and above, the conventional economic discounting models, such as hyperbolic discounting, describe intertemporal choice as a holistic comparison between two options, because these models assume people calculate the subjective utility of each option by applying a discount factor to weigh the outcome by its delay, and ultimately choose the option with the highest subjective utility. These models predict more looking within each option as people make these calculations. However, attribute-based models, like the tradeoff model, describe it as a comparison process made across options, along each attribute variable. It follows from this that people would look more within attributes, comparing each attribute across options.

Although a great deal of the research literature that has compared select models from each category (option- or attribute-based, see chapter 2.1 and 2.2) has been done by examining choice behaviour, there has been some process tracing to investigate attribute-based and option-based comparisons. Reeck, Wall and Johnson (2017) used Mouselab (see section 4.1.2) in a series of conventional delay discounting tasks to investigate whether differences in search strategy (i.e., attribute- or option-based) resulted from individual differences or from the choice options themselves. They found that *comparative searchers* tended to make more within-attribute comparisons and that they discounted less, whereas *integrative searchers* made more within-option comparisons. To investigate whether different search strategies *caused* different choice behaviours, the researchers introduced a small delay in revealing the information selected by the participant, using Mouselab, but only for the types of comparisons (attribute- or option-based) the researchers wanted to discourage, thus encouraging the opposite comparison type. Results showed that when participants were encouraged to make attribute-based comparisons, they discounted less, and when they were encouraged to make option-based comparisons, they discounted more. Not only do these findings show the invaluable contribution of process tracing in intertemporal choice, but specifically the role of mental processes in individual differences in delay discounting, and that these mental processes have a causal role in discounting.

With the aim of comparing option-based and attribute-based discounting models, Amasino and colleagues (2019) used multi-attribute drift diffusion modelling (DDM) to trace information accumulation while participants made choices between smaller-sooner and larger-later. They found that people made more attribute-based than option-based comparisons, and eye tracking data from intertemporal choice tasks showed that this was also reflected in participants' overt attention in conventional delay discounting trials. The above two studies represent the few attempts in the research literature to compare the mental processes involved in delay discounting.

The two studies in this chapter sought to compare the predictions made by option-based and attribute-based models by using eye tracking, as has been done for decision under risk and for game theory scenarios (Stewart et al., 2016a; 2016b). In these studies, researchers have identified what comparisons participants make by looking at whether they make more gaze transitions within attributes or within options. The following two studies seek to do the same comparisons between within-option and within-attribute transitions for conventional delay discounting tasks.

This thesis has previously covered the delay date effect as well as the episodic tagging effect, both of which reduce discounting. When the delays in conventional discounting tasks are presented as calendar dates (e.g., "22. June 2021") instead of the number of days, weeks, months or years (e.g., "in 10 months"), people are more likely to choose the larger-later over the smaller-sooner option. Similarly, when the delays, not given in a calendar format, are accompanied by episodic tags to remind the decision makers of their plans on the time of receipt, people also tend to choose the larger-later option. However, there is no additive effect of date-format and episodic tagging, suggesting that both may rely on underlying processes.

The following two studies aim to look broadly at the relative frequency of different transition types. They also aim to explore whether the change of mental processes, resulting from either date-formats or episodic tags, change what comparisons people make. Specifically, if people think more holistically about the moment of receipt when options are presented in a date-format or with episodic tags, and they therefore look more within options than across options within attributes. This shift in comparisons might reflect a change of processing from attribute-based to option-based processing. Because date-formats are harder to compare than the number of months to wait it is possible that this causes any observed differences in attribute-based vs. option-based comparisons made. However, this should not be the case with episodic tags as the number of months to wait is still retained on the screen along with the episodic tags.

In sum, the following two studies will monitor participants' eye movements while they carry out a series of binary delay discounting tasks. In study 4, the date/delay effect is examined by having comparing eye movements for delay-format and date-format, and in Study 5, the eye movements are compared in discounting conditions with or without episodic tags. As previous studies on decision involving risk, these studies will explore how much people look at the various on-screen attributes and what transitions people make between and within options. Each study will also use these fixation and transition observations to predict choice.

4.3 STUDY 4

4.3.1 RATIONALE

The purpose of this experiment was to use eye tracking to explore the processes underling intertemporal choice, specifically, binary choices between smaller-sooner vs. larger-later monetary choice options. The aim was to examine whether participants, in such discounting tasks, make more within-option or within-attribute transitions. The measurable proxy for within-option comparisons was the pattern of eye fixation transitions made from delay to amount and from amount to delay within each option. Within-attribute comparisons was measured as the pattern of eye fixation transitions made between from delay to delay and from amount to amount across options.

More within-option transitions would lend support to the option-based conventional models of discounting describing holistic option evaluation that combines values and delays. However, if participants make more within-attribute transitions, this suggest they are comparing the two amounts with one another, and the two delays with one another, lending support to attribute-based models of discounting.

Another aim was to examine whether the amount of larger-later choices an individual makes can be predicted by whether they make within-option or within-attribute transitions. Previous models of discounting have sought to explain discounting by observing behavioural data, and explaining it by the numerical variables of the delays and the amounts, as well as context variables. However, eye movements may be able to predict a portion of choice behaviour these other variables cannot account for.

As mentioned in the literature review for this chapter, the date/delay effect influences discounting in that delays written in a date-format make people choose the larger-later option. So, this study sought to examine this well-established effect while monitoring decision makers' eye movements. As this effect influences discount rates, it could be that it also influences the types of comparisons made. More specifically, given how the date/delay effect attenuates discounting, it might be doing so by the types of comparisons and thus transitions it prompts people to make, which in turn lead to different discount rates. Because dates are harder to compare than delays, one would expect people to shift their comparison strategy from attribute-level comparison for delay formats, to a more holistic option-based comparison strategy for date formats.

All predictions are listed below, where H2 is the key prediction of interest, H1 a mere replication of the date/delay-effect, and H3 follows from H1 and H2.

- H1: Less discounting when delays are written as dates than as months.
- H2: More within-option transitions for the date than for the date condition.
- H3: More within-option transitions predict more discounting in both conditions.

Unplanned exploratory analyses did not have any clear set predictions. However, it logically follows that greater fixation duration would predict more large-later choices (i.e., less impulsive choices). Moreover, the gaze-cascade effect predicts that people look progressively more at the choice they prefer and ultimately choose. These predictions would be the same across date- and delay-conditions.

4.3.2 METHODS

In study 4, participants made a series of intertemporal choices in the lab while their eye movements were recorded. Their eye movements and choice behaviour were measured for both the delay- and date-conditions. For each condition, eye movements were measured as fixation duration on, and transitions between, the on-screen attributes. Participants, apparatus, stimuli, counterbalancing design and procedure are detailed below.

4.3.2.1 PARTICIPANTS

The 60 participants (60.3% female, age range: 18-53, median: 26) who took part in this study were recruited through City University of London's participant recruitment systems. They were paid £8 per hour for the 15-minute study, which was carried out simultaneously as the much longer Study 3. Study 4 was carried out first so as to avoid any fatigue effects from Study 3. Data from 5 participants were replaced with 5 new participants due to validity problems with the eye tracking data. Written consent was obtained by all participants in accordance with City University's research ethics committee.

4.3.2.2 APPARATUS

The experiment was run on E-Prime 2.0 using a Tobii TX300 monitor with a resolution of 1920 x 1080 and 300 Hz refresh rate. Eye movements were tracked at a sampling rate of either 120 Hz or 300.[4]

4.3.2.3 STIMULI

Each trial presented a simple binary choice between a smaller-sooner (*SS*) and a larger-later (*LL*) amount of money (e.g., £40 in 1 month or £70 in 4 months) in a 2x2 display. There were 25 choices in total, 12 of which were obtained from Read et al (2005; *k*-values ranging from .025 to .05), and 12 were novel choices based on similar k-values to the first 12 choices, ranging from .023 to .051 as per hyperbolic discounting;

$$k = \frac{(LL\ amount - SS\ amount)}{((SS\ amount\ x\ LL\ delay) - (LL\ amount\ x\ SS\ delay))}$$

The remaining choice was a catch-trial to detect participants who did not pay full attention to the study. These consisted of an inferior smaller-later (SL) option and a superior larger-sooner (LS) option. The four participants who failed one or both catch trials were excluded from the study and replaced.

Participants were presented with two of these blocks of 25 trials. These blocks were identical apart from the delivery-time format: In one block the options were presented in the conventional delay-format (e.g., £40 in 1 month or £70 in 4 months), whereas the other block was presented in a date-format (e.g., £40 in on February 1st 2017 or £70 on April 1st

[4] The sampling rate differed across participants because it had been inadvertently set to a different rate by another user and it was not picked up. The different sampling rate had no effect on the overall results as they were equally distributed across conditions. Moreover, while the intended sampling rate was 120 Hz, the more fine-grained 300 Hz had no effect on the overall results as eye fixations were measured for 4 relatively large areas of interest.

2017; Read et al., 2005). Whether the participants were presented with the delay- or date-format first was randomised.

The choice attributes were presented in black writing on a white background, in font size 18, so that eye movements were necessary to sufficiently read the writing. An illustration of the stimuli can be seen in Figure 4.2, Figure 4.3, (delay-format), and Figure 4.4 (date-format).

4.3.2.4 COUNTERBALANCING DESIGN

The choices were either aligned vertically, with a left and a right option, or horizontally, with a top and a bottom option. The delays were either shown first (to the left in the vertical alignment, or on top of the horizontal alignment) or last. These 4 possible alignments were counterbalanced in a 2x2 design with 15 participants presented with each alignment. This way preferred reading direction would not bias the result while simultaneously not confusing the participant by introducing different alignments from trial to trial. See figure 4.1 for an illustration of the different arrangements between-participants.

The order of the 25 choices within each block were randomised, as were the order of the two choice options, so that the SS-option would only appear first (left in the vertical alignment; on top in the horizontal alignment) in half the trials.

Figure 4.1: The 4 possible alignments in the 2 x 2 counterbalancing design.

A

Delay 1	**Delay 2**
Amount 1	**Amount 2**

C

Delay 1	**Amount 1**
Delay 2	**Amount 2**

B

Amount 1	**Amount 2**
Delay 1	**Delay 2**

D

Amount 1	**Delay 1**
Amount 2	**Delay 2**

Note. Arrangements A and B sow the options side by side, with arrangement A displaying the delays on top of the amounts and arrangement B displaying the amounts on top of the delays. Similarly, arrangements C and D show the options stacked, with arrangement C displaying the delays to the left of the amounts, and arrangement D displaying the amounts to the left of the delays. For all 4 arrangements, the left/right or top/bottom order of the two options were randomised within participants on a trial-by trial basis.

4.3.2.5 PROCEDURE

The experiment started with a nine-point calibration of the eye tracker, a procedure which would be repeated immediately if the first calibration was not satisfactory. Participants were then instructed to make hypothetical choices between two sums of money delivered at different times. There were no practice trials as the format was easily comprehended during pilot testing. A drift-correction at the onset of each trial displayed a fixation cross at the middle of the screen. Participants were required to fixate on this cross for 1 second in order to proceed to the following trial. Each choice-matrix was on-screen from after the drift-correction until the participant had made their choice. Participants responded by pressing the following keys in vertical alignments: “a” (left) and “l” (right), and for horizontal alignments: “t” (top) and “b” (bottom).

4.3.3 RESULTS

Choice behaviour was measured by counting the number of larger-later option choices out of 24 binary choice-tasks for each of the date and delay conditions. From the means it appears that larger-later options were more often chosen in the date condition (M = .35, SD = .31) than in the conventional delay condition (*M* = .23, *SD* = .26). This difference was significant in a paired samples t-test, $t(59) = 4.398$, $p < .001$, $d = .568$, replicating the findings of Read et al. (2005) and confirming the hypothesis (H1). This analysis was well-powered ($n = 60$, $\alpha = .001$, $1 - \beta = .991$) as revealed in the post-hoc power analysis.

4.3.3.1 EYE MOVEMENTS

Eye movements were recorded into x and y co-ordinates for the left and the right eye along with their durations. The *R* package *Saccades* (von der Malsburg, 2015) was used to average the co-ordinates across eyes and extract them into fixations and transitions. This package detects fixations in raw eye tracking data, using a velocity-based algorithm to identify saccades, and classify anything between two saccades as a fixation. The variation in sampling rates across participants were corrected for in this analysis by using the actual times as recorded in the data file, instead of sampling rate.

There were some irregularities with the data output that needed further cleaning. First, for the instances where cells were lacking any data, mostly due to eyes blinking, the assumption was that people were still fixating on whatever attribute they were fixating on the same attribute as before. Second, the few corrupted rows were removed entirely from the data set.

Depending on their x- and y- co-ordinates, fixations were grouped into one of 5 areas of interest: smaller-sooner amount, smaller-sooner delay, larger-later amount, larger-later delay and the fixation cross.

4.3.3.2 FIXATION DURATIONS

Table 4.1 shows the total mean absolute and mean proportionate looking duration (in milliseconds) on each of the 4 on-screen areas of interest for each of the two conditions. People spent more overall time looking in the date condition (*M* = 94 sec) than in the delay condition (*M* = 76 sec), $t(59) = 4.754$, $p < .001$, $d = .614$. This analysis was well-powered as per the post-hoc power analysis ($n = 60$, $\alpha = .001$, $1 - \beta = .997$). Descriptively, the absolute means show similar fixation durations for amounts in both the delay (SS amounts: *M* = 19 sec, LL amounts: *M* = 19 sec) and date (SS amounts: *M* = 18 sec, LL amounts: *M* = 18 sec) conditions. However, people spent more time looking at delays in the date condition (SS delays: M = 29 sec, LL delays: M = 30 sec) than in the delay condition (SS delays: M = 18 sec, LL delays: M = 20 sec).

Table 4.1: Absolute means (St.dev) of fixation duration per condition.

	Delay	Date
SS amounts	18.8 (9.0)	18.0 (9.4)
SS delays	17.7 (7.9)	29.7 (15.8)
LL amounts	19.1 (9.5)	18.3 (10.2)
LL delays	20.3 (11.2)	29.6 (16.2)
Total	75.8 (34.6)	95.0 (48.8)

Note. The mean (standard deviation) absolute amount of fixation duration (seconds) for each of the four areas of interest and the total for the four areas, for the delay and date condition each.

Table 4.2: Means (St.dev) for the proportion of fixation duration for per condition.

	Delay	Date
SS amounts	.25 (.04)	.19 (.04)
SS delays	.24 (.05)	.30 (.06)
LL amounts	.25 (.05)	.20 (.06)
LL delays	.26 (.05)	.31 (.05)

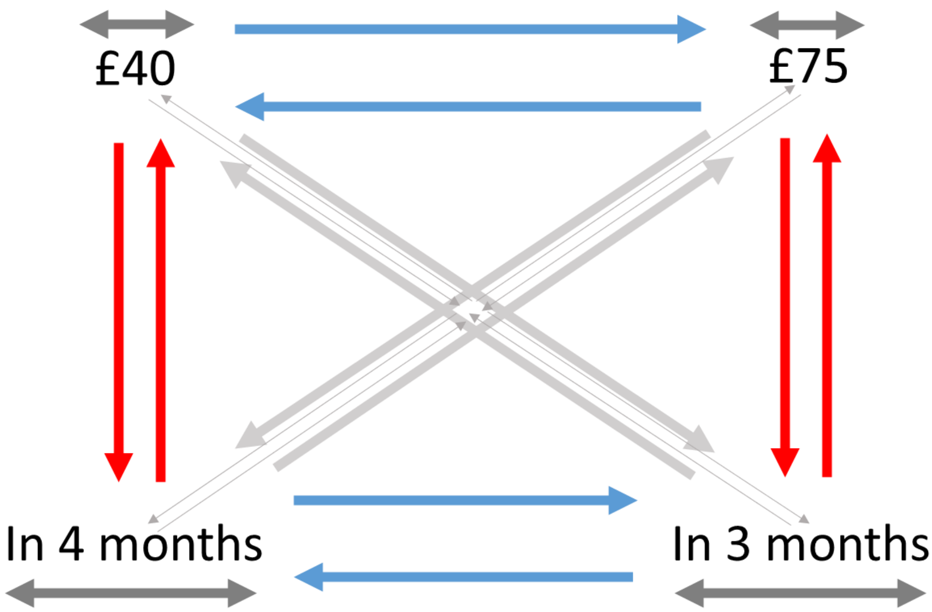
Note. The mean (standard deviation) proportionate amount of fixation duration for each of the four areas of interest and the total for the four areas, for the delay and date condition each.

The proportion of looking time for each of the areas of interest, out of the total looking times on all 4 areas of interest, revealed a different pattern in the two conditions. In the delay condition, looking time was relatively evenly distributed across the four pieces of information, whereas in the date condition, participants spent a notably higher proportion of their time looking at the information about the time of receipt. Combining across delays for each of the two conditions (SS delay + LL delay) showed that people spent significantly proportionately longer looking at delays in the date condition (M = .610, SD = .081) than in the delay condition (M = .499, SD = .081), $t(59) = 10.804$, $p < .001$, $d = 1.029$. Post-hoc power analysis showed that this analysis was well-powered (n = 60, $\alpha = .001$, $1 - \beta = 1$).

4.3.3.3 TRANSITIONS

From the extracted fixations, transitions made between the areas of interest were calculated. For example, if an 'SS delay fixation' was followed by a 'SS amount fixation', this would be counted as a 'SS delay → SS amount' transition. There were 24 transition categories in total, as illustrated in Figure 4.2, of which 8 would be classified further: the example 'SS delay → SS amount earlier would be classified as a *within options* transition, as would 'LL delay → amount', 'SS amount → SS delay' and 'LL amount → LL delay'. The transitions "SS delay → LL delay', 'LL delay → SS delay', 'SS amount → LL amount' and 'LL amount → SS amount' would be classified as a *within attribute* transition. In Figure 4.2, the blue arrows indicate transitions made within attributes, and the red arrows are the transitions made within options. The diagonal transitions in light grey and the within-item transitions in dark grey were not included in the analysis. Out of the total sum of 8 within-option and within-attribute transitions, proportions of either within-option and within-attribute transitions were calculated to form a within-attribute transition variable and a within-option transition variable.

Figure 4.2: An example trial showing the 24 transition categories.



Note. This is an example of the stimuli and its on-screen arrangement in a trial from the delay-format condition. Note that this is not a screenshot, as the arrows are not visible to the participants. These arrows are added here in order to illustrate the different types of transitions referred to in this study.

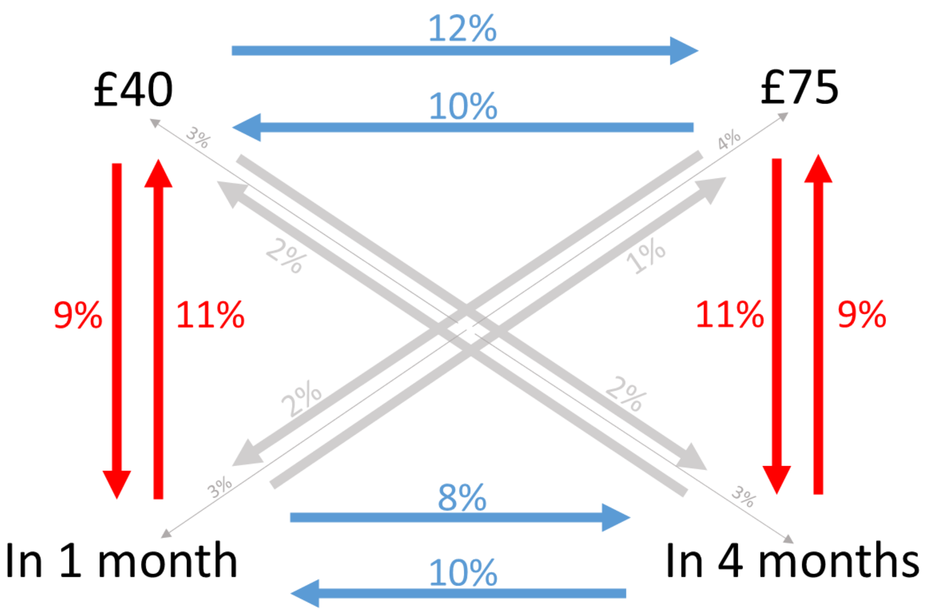
Blue arrows indicate within-attribute transitions and red arrows indicate within-option transitions. The four grey horizontal transitions represent the transitions made within each attribute, and the four grey diagonal transitions represent when participants transitioned across options and attributes (e.g., from the amount of one option to the delay of the other option). Lastly, the eight thin grey lines represent transitions between the fixation cross to either of the four attributes.

Table 4.3: Means (St.dev) for proportional transitions in the delay condition.

	SS AMT	SS DEL	LL AMT	LL DEL	FIX
SS AMT	-	**.09 (.04)**	**.12 (.04)**	.02 (.01)	.00 (.00)
SS DEL	**.11 (.03)**	-	.01 (.01)	**.08 (.02)**	.00 (.00)
LL AMT	**.10 (.03)**	.02 (.01)	-	**.11 (.03)**	.00 (.00)
LL DEL	.02 (.02)	**.10 (.03)**	**.09 (.03)**	-	.00 (.00)
FIX	.03 (.03)	.03 (.03)	.04 (.03)	.03 (.03)	-

Note. Means (standard deviations) for the proportion of transitions made between each attribute for the delay condition. Fixations went from the attributes in the first column to the attributes in the first row. AMT = amount, DEL = delay, FIX = fixation cross, SS = smaller-sooner, LL = larger-later. The eight transition types of interest (4 within-option and 4 within-attribute) are highlighted in bold.

Figure 4.3: The means, that were greater than zero, from Table 4.3 (delay-format).



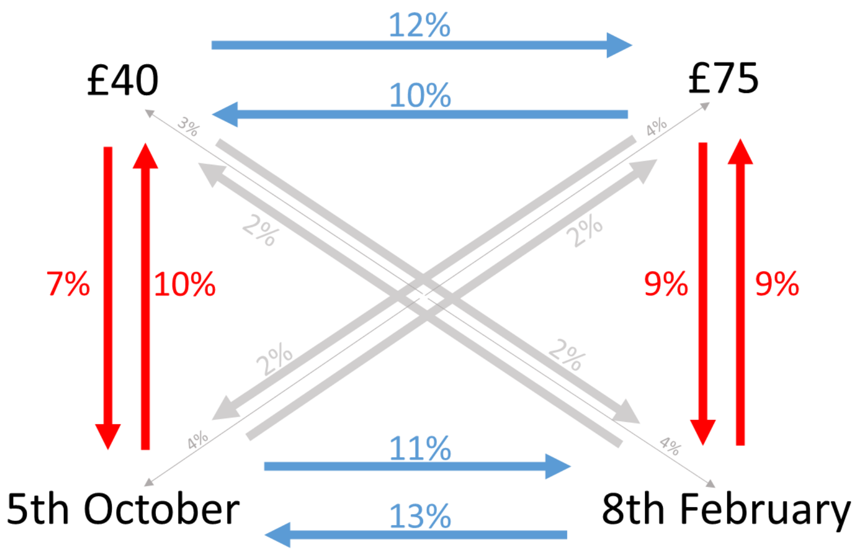
Note. These are the means for the proportion of transitions made between each attribute for the 'delay condition'. Means smaller than 0% were excluded from this figure.

Table 4.4: Means (St.dev) for proportional transitions in the date condition.

	SS AMT	SS DEL	LL AMT	LL DEL	FIX
SS AMT	-	**.07 (.03)**	**.12 (.03)**	.02 (.01)	.00 (.00)
SS DEL	**.10 (.04)**	-	.02 (.01)	**.11 (.04)**	.00 (.00)
LL AMT	**.10 (.04)**	.02 (.01)	-	**.09 (.03)**	.00 (.00)
LL DEL	.02 (.01)	**.13 (.04)**	**.08 (.03)**	-	.00 (.00)
FIX	.03 (.03)	.04 (.03)	.03 (.03)	.04 (.03)	-

Note. Means (standard deviations) for the proportion of transitions made between each attribute for the date condition. Fixations went from the attributes in the first column to the attributes in the first row. AMT = amount, DEL = delay, FIX = fixation cross, SS = smaller-sooner, LL = larger-later. The eight transition types of interest (4 within-option and 4 within-attribute) are highlighted in bold.

Figure 4.4: The means, that were greater than zero, from Table 4.4 (date-format).



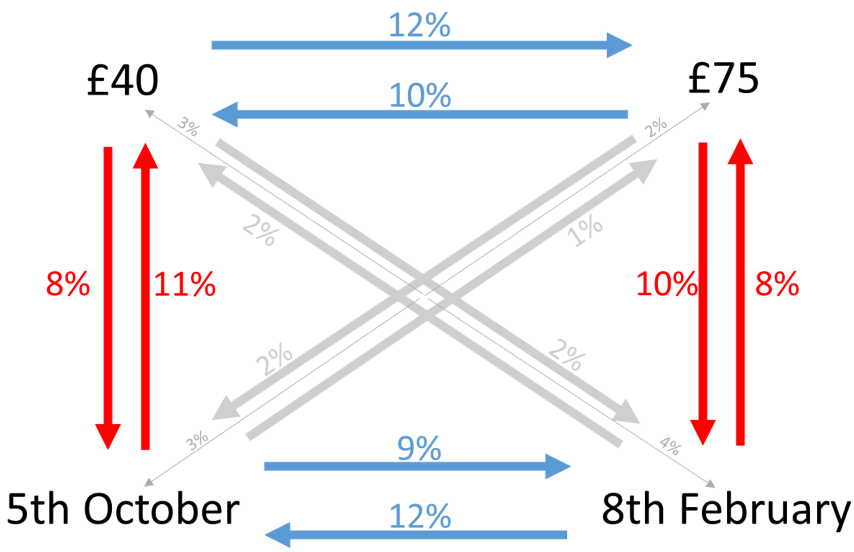
Note. These are the means for the proportion of transitions made between each attribute for the 'date condition'. Means smaller than 0% were excluded from this figure.

Table 4.5: Means (St.dev) for the proportion of transitions for both conditions collapsed.

	SS AMT	SS DEL	LL AMT	LL DEL	FIX
SS AMT	-	**.08 (.03)**	**.12 (.04)**	.02 (.01)	.00 (.00)
SS DEL	**.11 (.03)**	-	.01 (.01)	**.09 (.03)**	.00 (.00)
LL AMT	**.10 (.03)**	.02 (.01)	-	**.10 (.03)**	.00 (.00)
LL DEL	.02 (.01)	**.12 (.03)**	**.08 (.03)**	-	.00 (.00)
FIX	.03 (.03)	.03 (.03)	.02 (.01)	.04 (.03)	-

Note. Means (standard deviations) for the proportion of transitions made between each attribute for both conditions collapsed. Fixations went from the attributes in the first column to the attributes in the first row. AMT = amount, DEL = delay, FIX = fixation cross, SS = smaller-sooner, LL = larger-later. The eight transition types of interest (4 within-option and 4 within-attribute) are highlighted in bold.

Figure 4.5: The means in table 4.5 that were greater than zero.



Note. These are the means for the proportion of transitions made between each attribute for both conditions collapsed. Means smaller than 0% were excluded from this figure.

Table 4.3 shows the proportions of transitions made for the delay condition, and Table 4.4 shows the proportions of transitions made for the date condition. Figure 4.3 and Figure 4.4 illustrate these, respectively. Table 4.5 and the associated illustration in Figure 4.5 show the transitions made across conditions. All three tables show that people make little to no transitions from a particular attribute to the fixation cross, and they make no more than 4% of their transitions *from* the fixation cross to a particular attribute. This 4% likely reflects the first transition made, which always starts at the fixation cross. The greatest transitions are the most meaningful ones, ranging from 7% to 14%, where people compare one attribute to either the other attribute of the same option *or* the same attribute of the other option. Transitions made between an attribute of one option and a different attribute of the other option only ranged from 1% to 2%, suggesting people were not comparing these much. All of the above 3 tables and 3 figures suggest people make more within-attribute transitions (range: 8% - %13) than they do within-option transitions (range: 7% - %11).

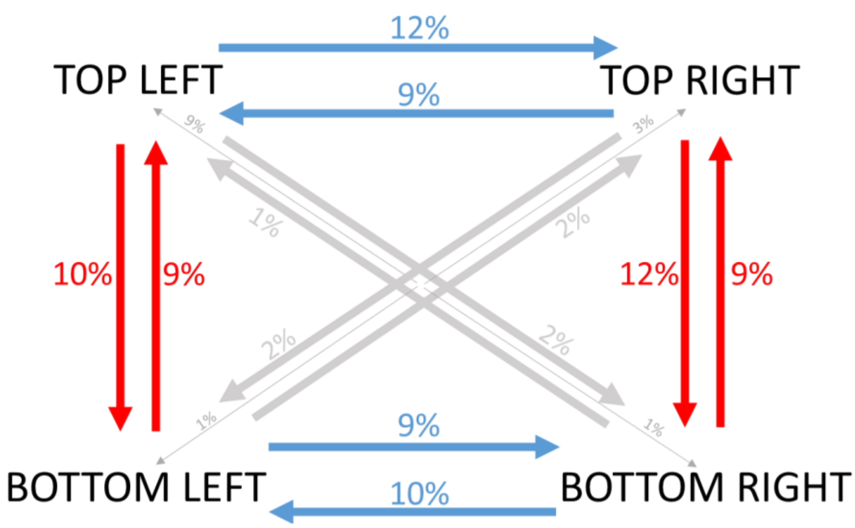
There was a significant difference in proportion of within-option transitions between the *delay* (M = .5077, SD = .0911) and *date* (M = .4299, SD = .0892) conditions, $t(59) = -7.530$, $p < .001$, with the *date* condition having more within-attribute transitions. This was in the opposite order of the hypothesis, which predicted that there would be more within-option transitions in the date-condition relative to the delay-condition (H2). The analysis was well-powered as per the post-hoc power analysis (n = 60, α = .001, $1 - \beta$ = .1). Thus, when the delays were presented as dates rather than number of months, participants were more likely to compare the attributes across options relative to comparing the values and delays within options.

Table 4.6: Proportions of transitions made per location across conditions.

	TOP LEFT	BTM LEFT	TOP RIGHT	BTM RIGHT	FIX
TOP LEFT	-	**.10 (.04)**	**.12 (.05)**	.02 (.01)	.00 (.00)
BTM LEFT	**.09 (.03)**	-	.02 (.02)	**.09 (.04)**	.00 (.00)
TOP RIGHT	**.09 (.04)**	.02 (.02)	-	**.12 (.04)**	.00 (.00)
BTM RIGHT	.01 (.01)	**.10 (.03)**	**.09 (.04)**	-	.00 (.00)
FIX	**.09 (.04)**	.01 (.03)	.03 (.04)	.01 (.02)	-

Note. Means (standard deviations) for the proportion of transitions made between location across conditions. Fixations went from the attributes in the first column to the attributes in the first row. BTM = bottom, FIX = fixation cross. The eight transition types of interest (4 within-option and 4 within-attribute) are highlighted in bold.

Figure 4.6: The means from Table 4.6 (both conditions) that were greater than zero.



Note. The 9% transition from fixation cross to top left shows that most participants started to look at the top-left attribute, relative to the 1-3% of the other transitions starting at the fixation cross. The eight within-option and within-attribute transitions only vary between 9-12% but the most frequent transition types of 12% are transitions from top-left to top-right and from top-right to bottom-right. Means smaller than 0% were excluded from this figure.

Table 4.6 and Figure 4.6 also showed proportionate transitions made, but this time based on *on-screen location* rather than the specific options and attribute fixated on. Both show that the most common transitions were made from the top left to the top right, and from the top right to the bottom right. The second most common transition were from top-left to bottom left and from bottom right to bottom left. This suggested that people were looking in reading order; i.e., largely from left to right, but also from top to bottom, and overall suggesting that people might have been transitioning between the on-screen attributes in a clockwise circular manner starting from the top left. The large transition from the fixation cross to the top left corner support this, as people always started out at the fixation cross at the beginning of each trial. This underscores the importance of counterbalancing for such looking preferences in the present study.

4.3.3.4 EYE MOVEMENTS PREDICTING CHOICE BEHAVIOUR

The previous sections examined what information the participants attended to when making intertemporal choices, irrespective of what choice they actually made. This section examines the relationship between these process measures and the choices made by participants. Compared to the date condition, the delay condition showed a stronger correlation between within attribute transitions and larger-later choices. A linear regression was carried out for each of the two conditions: the proportion of larger-later choices was the dependent variable and the proportion of within-attribute transitions was the independent variable. All regression analyses can be seen in Table 4.7.

Results showed that the proportion of within-attribute transitions did not predict the proportion of larger-later choices made in the *date* condition. However, more within-attribute transitions significantly predicted more larger-later choices in the *delay* condition, contrary to predictions that more within-option transitions would predict more larger-later choices (H3). Post-hoc power analyses showed that the analysis for the *date* condition was underpowered for the small-to-medium effect size (f^2 = .087), whereas the analysis for the *delay* condition was sufficiently powered to detect the large effect size (f^2 = .429).

Table 4.7: Predicting discounting with eye movements (Delay/Date).

	$F(1,58)$	p	r	f^2	α	1- β
Prop. within-attribute transitions						
Delay-format	**5.580**	**.022***	**.30**	**.429**	**.05**	**.999**
Date-format	.388	.536	.08	.087	.05	.613
Total fixation duration						
Delay-format	1.561	.220	.16	.190	.05	.914
Date-format	.161	.690	.05	.053	.05	.416
Prop. fixation on delays						
Delay-format	3.494	.070	-.24	.316	.05	1
Date-format	**9.991**	**.003***	**-.38**	**.613**	**.01**	**1**
Prop. fixation on LL option						
Delay-format	**11.848**	**.001***	**.41**	**.695**	**.001**	**1**
Date-format	**21.099**	**.000***	**.52**	**1.083**	**.001**	**1**
Prop. fixation on LL delay						
Delay-format	.040	.840	-.03	.031	.05	.268
Date-format	1.757	.190	-.17	.205	.05	.931
Prop. fixation on LL amount						
Delay-format	**10.549**	**.002***	**.39**	**.639**	**.005**	**1**
Date-format	**13.545**	**.001***	**.44**	**.786**	**.005**	**1**
Prop. fixation on SS delay						
Delay-format	**10.386**	**.002***	**-.39**	**.639**	**.005**	**1**
Date-format	**17.353**	**.000***	**-.48**	**.923**	**.001**	**1**
Prop. fixation on SS amount						
Delay-format	.018	.890	-.02	.020	.05	.193
Date-format	3.905	.053	.25	.333	.05	.993

* = Significant at .001-.05 (see α in table)

Note. This table shows the statistical analysis for whether the following could predict proportion of LL-choices relative to SS-choices: within-attribute transitions, total fixation duration and proportionate fixation duration, for each of the two conditions.

SS = smaller-sooner, LL = larger-later, Prop. = proportionate (within-attribute transitions in proportion to within-option transitions, fixation on delays in proportion to fixation on amounts, fixation on LL option in proportion to SS option, and fixation on either attribute in proportion to the other three attributes).

Table 4.8: Descriptive statistics for merged variables.

	Prop. fixation on delays *(prop. SS delay + prop. LL delay)*		Prop. Fixation on LL option *(prop. LL amount + prop. LL delay)*	
	Delay-format	Date-format	Delay-format	Date-formats
Mean	.498	.610	.515	.506
St.dev	.081	.095	.045	.035

Note. Means and standard deviations for proportionate fixation durations per option and attribute type. Here the proportionate fixation duration on each attribute were combined to create the following variables for each of the two delay conditions. The sum of proportionate fixation duration on SS (smaller-sooner) delays and LL (larger-later) delays formed the proportion of fixation duration on delays relative to the proportion of fixation duration on amounts. Likewise, the sum of proportionate fixation duration on LL amount and LL delay formed the proportion of fixation duration on the LL option relative to the SS option.

So far, all planned analyses for Study 4 have been carried out. What follows here are unplanned exploratory analyses that investigated what looking patterns could predict choice behaviour. Although one might expect impulsive choices such as discounting to be made quicker, total fixation duration did not significantly predict choices in either the delay condition (f^2 =.190) nor in the date condition(f^2 = .053). However, while looking proportionately more at delays did not predict choice in the delay condition (f^2 = .316*)* it did predict *fewer* larger-later choices (i.e., *more* smaller-sooner choices) in the date condition (f^2 = .613). Greater fixation duration on the larger-later option (proportionate LL amount + LL delay) predicted more larger-later choices for both the delay condition (f^2 = .695), and the date condition (f^2 = 1.083). Post-hoc power analyses showed that 5 of the above 6 analyses were well-powered, except the analysis predicting choice-behaviour from total fixation duration in the *date* condition too underpowered to detect the small effect size (f^2 = .053).

Table 4.9: Proportionate fixation duration per attribute.

	Prop. fixation on LL delays		Prop. Fixation on LL amounts		Prop. fixation on SS delays		Prop. Fixation on SS amounts	
	Delay	Date	Delay	Date	Delay	Date	Delay	Date
Mean	.262	.308	.253	.197	.236	.302	.249	.193
St.dev	.053	.047	.051	.060	.046	.059	.041	.040

Note. Means and standard deviation for proportionate fixation duration per attribute, for each condition. Descriptively, the delay condition has a fairly even .25 split, whereas the date-condition has more proportion fixation durations on delays relative to amounts.

Lastly, each of the proportionate looking times was investigated in turn for its ability to predict choice behaviour, as illustrated in Figure 4.7. Looking more at the larger-later delay did not predict choice behaviour for neither the delay condition (f^2 = .031*)* nor the date condition (f^2 = .205*)*. As for the larger-later amounts, greater fixation duration on this area of interest predicted more larger-later-choices for both the delay condition (f^2 = .639*)*, and the date condition (f^2 = .786). Post-hoc power analyses showed that 3 of the above 4 analyses were well-powered, except for the regression predicting choice-behaviour from larger-later delay fixation in the delay condition was too underpowered to detect the small effect size (f^2 = .031).

Greater looking times for the smaller-sooner delays predicted *fewer* larger-later choices (i.e., *more* smaller-sooner choices) for both the delay condition (f^2 = .639), and the date condition (f^2 = .923). Greater fixation duration for the smaller-sooner amount did not predict choice in the delay condition (f^2 = .020), though it was close to significance in the date condition, (f^2 = .333), showing a tendency for more larger-later choices. Among the above four analyses, post-hoc power analyses revealed that all were well-powered, except the regression prediciting choice-behaviour from smaller-sooner amount fixations in the delay condition was too underpowered to detect the small effect size (f^2 = .020).

Figure 4.7: Illustrating the fixation durations for the two conditions.

Delay

£45	**£70 (+)**
1 month (-)	3 months

Date

£45	**£70 (+)**
4 July 2020 (-)	1 Sept 2020

Note. Participants looked more at the larger-later amount, highlighted in green, when making a larger-later choice, and they looked more at the smaller-sooner delay, highlighted in red, when making a smaller-sooner choice. Overall, this shows that participants looked more at the most desirable attribute (i.e., shorter delays and larger amounts) of the option they went on to choose in both conditions.

4.3.4 DISCUSSION

The aim of this study was to investigate eye movements in intertemporal choice, both when delays were presented in the conventional delay format, and when presented as calendar dates. Specifically, the study compared the amount of within-option transitions compared to the number of within-attribute transitions were made. Traditional integration models predict that people will look more within options as they weigh amounts by delays to mentally calculate a subjective value and thus a holistic mental representation of the outcome. Conversely, more recent trade-off models predict that people will look more within attributes as they compare options along each attribute; comparing delays to delays and amounts to amounts.

The present study replicated the date/delay effect of Read et al. (2005) where people discounted less when delays were presented as calendar dates rather than as the number of months. Due to this significant difference, this discussion will be comparing and contrasting the eye movement data results for the delay condition and the date condition. This study sought to examine whether the date/delay effect led to a change in strategy from an attribute-level comparison in the delay condition to an option-based comparison in the date condition. The prediction was that, as the number of months are easier to compare, people would be more likely to make within attribute-transitions. And if the date effect is caused by the decision maker forming a mental representation of the given date, this would be reflected in more within-option transitions.

However, there was a significant difference between the conditions in the opposite direction. There were significantly more within-attribute transitions in the date condition relative to the delay condition. The greater proportion of within-option transitions in the delay condition supports the predictions of the traditional discounting models, such as hyperbolic discounting which describes how people weigh values by their delays. This is consistent with how participants in the present study looked more from attribute to outcome within an option than they looked across options along each attribute.

While the prediction was that there would be more within-attribute transitions in the delay condition as months are easier to compare than calendar dates, there appeared to be descriptively more fixation durations on the delays in the date condition. Moreover, there was significantly more proportionate fixation duration on delays in the date condition than in the delay condition. As discussed earlier, attribute-level comparisons of dates are more difficult than comparing delays, and so this might require more mental processing, which in turn would be reflected in eye movements. It is therefore possible that the difficulty in comparing calendar dates led to *more* transitions between delays specifically, and that this was driving the greater portion of within-attribute transitions in the date condition relative to the delay condition.

Further, the study explored whether eye movements could predict choice behaviour. While there were proportionately more within-attribute transitions in the date condition, the proportion of within-attribute transitions did not predict choice behaviour in the date condition. However, it did predict choice behaviour in the delay condition, where more within-attribute transitions was associated with more larger-later choices, i.e., less discounting. It could be that the greater portion of within-attribute transitions in the date condition was not a reflection of processing that influenced discounting behaviour, but simply a reflection of dates being harder to compare.

As for fixation durations on delays, more fixation durations on delays did not predict choice in the delay condition. However, greater fixation duration on delays in the date condition predicted more discounting in the date condition. That is, people were more likely to choose the smaller-sooner option when looking more at delays. These findings are interesting given the aforementioned findings that the date condition showed both more proportionate fixation duration on delays, and more larger-later choices (i.e., less discounting) than in the delay condition. One explanation for this could be that the reason people choose more larger-later options in the date condition is *because* date are harder to represent in a way that allows for comparisons to be made. Consequentially people under-weigh the date-format delays and show greater patience for the larger-later option. However, if the decision makers *do* persevere and make sense of the temporal difference between the dates, this makes them over-weigh the dates, and thus put them off wanting to wait for the larger-later option and discount more.

When looking at the other eye movement patterns that could potentially predict choice behaviour, total fixation duration could not predict discounting in either condition. Looking more at the larger-later option predicted greater likelihood of choosing that option in both conditions. This is consistent with the gaze cascade hypothesis which simultaneously predicts that people look more at the option they prefer, but also that they end up preferring the option they look at the, as a positive feedback-loop (Shimojo et al., 2003). The present study only shows a positive relationship between gaze and preference that fits with this idea.

When predicting choice based on proportionate fixation duration on each attribute, choice behaviour could not be predicted by fixation duration on neither the larger-later delay nor the smaller-sooner delay in either condition. However, in both conditions greater fixation duration on the larger-later amount predicted more larger-later choices. In the same vein, looking more at the smaller-sooner amount predicted more smaller-sooner choices. These findings are unsurprising but reasonable as the shorter waiting time is the most attractive attribute in the smaller-sooner option, and the greater outcome is the most desirable attribute in the larger-later option. Thus, it appears that people look more at what they want and choose accordingly.

4.3.4.1 LIMITATIONS

One potential limitation of this study is that the near even split between within-attribute and within-option transitions might be due to a combination of reading order and the counterbalancing design that was employed to counteract reading order from skewing the results. The between-subjects counterbalancing designed was made so that ¼ of participants saw options stacked and delays first, ¼ saw options stacked and delays second, ¼ saw options side by side and delays first, and ¼ saw options side by side and delays second. However, when looking at reading order in Figure 4.6, it appears that people largely went from the fixation cross to the upper left attribute regardless, then directing their gaze to the top right attribute and then down to the bottom right attribute and possibly towards the bottom left attribute. Once counterbalancing was in place, this would result in an even split between what appears to be within-attribute and within-option reading order. In order to explore this possibility further one would need to explore the temporal order between each attribute location.

Another limitation of this study, which may apply to all multiple-trial studies of this variety, is that as participants may change strategy over time as they have to complete a great number of choice trials. All the trials are relatively similar to one another, so participants are likely to want to finish them quickly, and so may shift their decisions strategy to one that is more efficient. This may thus not accurately reflect what decision processes take place in life outside the lab. To work around this issue, one might want to explore only the first trial, or the first couple of trials. Alternatively, one could look at the effect of trial number on transition types, to explore how transitions change over the course of the experiment. But in order to retain power this would require a much greater number of participants.

4.3.4.2 CONCLUSION

In conclusion, people make more within-option transitions in the conventional delay discounting task. While more recent tradeoff based models have been on the rise in the delay discounting literature lately, the findings neither support these models nor the traditional discounting models that describe how decision makers weigh outcomes by delays before they make their choice. If anything, people appear to use a combination of attribute- and option-based processing. Contrary to predictions, people made more within-attribute transitions when delays were presented as calendar dates than in the conventional delay format, and this difference largely came down to greater fixation duration on delays in the date condition than in the delay condition. Moreover, more within-attribute transitions predicted more larger-later choices in the delay condition only, while more fixation durations on delays predicted more discounting in the date condition. One could speculate that this is because dates are harder to compare, and so when failing to compare dates people under-weigh the delays and discount less, but when they successfully compare dates they over-weigh the delays and discount more.

4.4 STUDY 5

4.4.1 RATIONALE

This experiment sought to employ an eye tracking methodology to investigate what processes and mental representations underlie intertemporal choice in the form of smaller-sooner and larger-later binary choices. As with Study 4, the primary aim was to examine whether decision makers make more within-option or within-attribute transitions, as a reflection of what comparisons people make. The overall format of the present study is a replication of the basic investigation of fixations and transition of Study 4. It is also an extension of Study 4. As the present study seeks to explore the processes involved episodic tagging effect in the same way Study 4 did for the date/delay effect.

To recount from Study 4, the prediction was that there would be more within-attribute transitions if people compare amounts to amounts and delays to delays, while within-option transitions would reflect a weighing of amounts by their delays. In short, within-attribute transitions would lend support to attribute-based models such as the Tradeoff model (Scholten & Read, 2010), whereas within-option transitions would weigh in favour of traditional discounting models such as the Hyperbolic discounting model (Loewenstein & Prelec, 1992).

The present study also sought to explore this in the context of the episodic tagging effect. The literature shows how delays presented with episodic tags leads to less discounting than when there are no episodic tags (Peters & Büchel, 2010). Earlier the date/delay effect was examined while tracing eye movements, to see if its effect on discount rate could be because this effect influences what comparisons people make. In a similar vein, the study sought to explore the episodic tagging effect with the eye tracker. The presence of episodic tags reminding people of their future plans could change their strategy to a more holistic evaluation of options.

Following the same rationale as in Study 4, because episodic tags influence discount rates by having people discount less, it might also affect what comparisons people are making. That is, people may shift from evaluating an option from an attribute-based level, to an option-based level, because the episodic tags are harder to compare directly and the episodic tags make people mentally represent the future event, which the episodic tags represents, holistically. Thus, there should be more within-option transitions when delays are episodically tagged, and relatively more within-attribute transitions when they are not tagged.

However, the previous findings of this thesis may suggest the opposite findings. First, in the episodic future thinking research strand of this thesis, there was an interaction effect within the date/delay effect and the episodic tagging effect, where there was no further attenuation of discounting from episodic tagging if delays were already written in calendar dates. This suggests the effects may be based on the same underlying mental representation. Second, the findings of Study 4 were contrary to predictions, with there being more within-attribute transitions in the date-format than in the day-format. So, while the a-priori predictions are that there will be more within-option transitions when delays are tagged, the findings of this thesis suggest the opposite; that there should be more within-attribute transitions when delays are episodically tagged.

Each condition was compared with one another in terms of total fixation duration. No specific hypotheses were set for these comparisons, although it would make sense that more impulsive choices (i.e., fewer LL-choices) would have less fixation duration as these are made quicker.

As for the comparison between each condition in terms of amount of proportionate within-option relative to within-attribute transitions. These were the a-priori predictions. However, considering the results of Study 3, if the date/delay and episodic tagging effects are based on a shared mechanism, one would expect the opposite of these predictions.

- H1a: None vs. SS tagged – More within-option transitions in SS tagged.
- H1b-c: LL vs. None or SS tagged - More within-option transitions in LL tagged.
- H1d-f: Both vs. None or SS or LL tagged – More within-option transitions in Both tagged.

Within each condition the extent to which transition type could predict choice behaviour. Again, given the possibility that the date/delay and episodic tagging effects share underlying mechanisms, one would expect the opposite of these predictions:

- H2a-d: In each condition – More within-option transitions predict more LL-choices.

Exploratory analyses did not have any clear set predictions, but some were derived from the gaze-cascade effect where people look progressively more at what they prefer and ultimately choose. The same predictions are made across the four conditions.

4.4.1.1 Attentional vs. episodic accounts for the tag-effect

Finally, the study addressed a potential confound in the study by Peters and Büchel (2010), in which only the larger-later delays were tagged, and compared with when both options were untagged. The potential confound here is that the episodic tag may be more of an attentional effect than an episodic one. People may simply choose the option that attracts their attention more, and a visual XXXXXXXX control is still not a fully comparable control to an episodic tag. In order to differentiate whether the tag effect is attentional or episodic, there were another two conditions in addition to 'none tagged' and larger later tagged'; 'smaller sooner tagged' and 'both tagged'. In these two conditions the smaller-sooner delay would have an episodic tag.

If the tagging effect is purely attentional, then 'none tagged' and 'both tagged' should have the same effect as they both should attract attention the same. However if the tagging effect is purely episodic, 'both tagged' should reduce discounting relative to 'none tagged'. The near future should be episodically construed by default, tagged or not, so the episodic tag can only change how the decision maker mentally represent the distant future. When the larger-later delay is construed episodically, it should be considered more on the same level as the smaller—sooner delay, and because of the larger outcome, the larger-later option should be chosen more, and discounting be reduced.

Similarly, if the tagging effect is purely attentional, the ‘smaller sooner tagged’ should have *more* discounting than the ‘none tagged’ condition. This is because the episodic tag for the smaller-sooner option draws attention away from the larger-later option, and thus people choose the smaller-sooner option more. If the effect is episodic, there should not be any difference between the ‘smaller sooner tagged’ and ‘none tagged’ as the immediate future is already episodically construed, and thus the episodic tag will not change its mental representation.

If the episodic effect disappears in the ‘both tagged’ condition, compared to the ‘larger later tagged’ condition, this suggest an attentional effect. However, if the effect is present and discounting is reduced it suggests the episodic tag changes the mental representation of the larger later option in a way that it does not to the smaller sooner option, as they are both tagged. Both the attentional and episodic effect hypotheses suggest less discounting in the ‘both tagged’ condition relative to the ‘smaller sooner tagged’ condition. It is either reduced because the attentional effect of the episodic tag is equal for the two options, or because the larger-later option is tagged and this reduces discounting, relative to when only the smaller-sooner option is tagged.

Finally, if the episodic effect is attentional, the ‘both tagged’ condition should lead to more discounting as the attention is now equal between the two option rather than just with the larger-later option. However, if the effect is episodic, there should not be any difference, as the larger-later delay is tagged in both conditions, and whether the smaller-sooner delay is tagged should not change the already episodic mental representation of that option. All predictions can be viewed succinctly in Table 4.10.

Table 4.10: Episodic tag predictions from attentional and episodic accounts.

	None tagged	SS tagged	LL tagged
SS tagged	SS / Same		
LL tagged	LL	LL	
Both tagged	Same / LL	LL	SS / Same

Note. An overview of whether episodic tags make people choose the smaller-sooner (SS) or larger-later (LL) option in one condition (column 1) relative to another (row 1). These predictions are derived from an (attentional account / episodic account).
The attentional account predicts that people choose whichever option is tagged because it draws attention. Meanwhile, an episodic account predicts that people choose the LL option when it is tagged because the tag makes it mentally represented as more temporally proximate to the SS option.

A summary of the above 8 behavioural predictions when comparing two conditions follows. An attentional account lead to the following predictions:

- H3a: None vs. SS tagged – More LL-choices in None tagged.
- H3b: None vs. Both tagged – No difference in LL-choices.
- H3c: LL vs. Both tagged – More LL-choices in LL-tagged.

An episodic account lead to the following predictions:

- H4a: None vs. SS tagged – No difference in LL-choices.
- H4b: None vs. Both tagged – LL-choices in Both tagged.
- H4c: LL vs. Both tagged – No difference in LL-choices.

And both the episodic and the attentional accounts predict

- H5a: None vs. LL tagged – More LL- choices in LL tagged.
- H5b: SS vs. LL tagged – More LL-choices in LL tagged.
- H5c: SS vs. Both tagged – More LL-choices in Both tagged.

4.4.2 METHODS

Like Study 4, Study 5 was a lab-based study in which participants made a series of intertemporal choices in the lab while their eye movements were recorded. In the present study, their choices and eye movements were measured in 4 episodic tag conditions. For each of these conditions, eye movements were measured as fixation duration on, and transitions between, the on-screen attributes. Participants, apparatus, design, stimuli, counterbalancing design and procedure are detailed below.

4.4.2.1 PARTICIPANTS

As with Study 4, the 60 participants (age range: 18-56, median: 28, 50% female) taking part in *Study 5* were recruited through City University of London's Sona systems. Six participants were excluded as they failed at least one of the two catch-trials described below, making the total participant count 54. The hourly pay was £8 and the study lasted for about 50 minutes.

4.4.2.2 APPARATUS

The eye tracking part of the experiment was run on E-Prime 2.0 using a Tobii TX300 monitor with a resolution of 1920 x 1080 and 300 Hz refresh rate, tracking eye movements at a sampling rate of 300 Hz.

4.4.2.3 DESIGN AND STIMULI

The experiment consisted of three parts. The first measured participants' discount rates; the second used the episodic tag generation procedure employed Study 2 and 3; and the third used the eye tracker to measure participants' eye movements while making intertemporal choices. The present study changed from the fixed discount options in Study 4 to options based on participants' discount rates. Because participants set the time for their own EFTs, the experiment could then use individual participants' discount rates to generate trials that were set at the time of the EFT and still posed a dilemma to the given participant.

4.4.2.3.1 Part 1: Initial discounting measurement

Participants completed the Three-option Adaptive Discount rate measure, abbreviated to ToAD (Yoon & Chapman, 2016), to obtain participants' discount rate. By having participants use between three options per trial, a precise discount rate can be obtained with only 10 questions, in less than a minute. The resulting discounting parameter, *k*, was used to generate tailored trials (specifically: smaller-sooner amounts) for participants in part 3 of the study.

4.4.2.3.2 Part 2: Episodic tag generation

This section was used to elicit a series of future events for a participant at specific points in time. The procedure was exactly that of the episodic tag generation of Study 2 and 3 in the previous chapter. In short, participants were given a verbal cue and asked to think of a personal future event set at a particular time in the future. Then they wrote down a description of this event, and crucially, a verbal label that would later serve as an episodic tag.

4.4.2.3.3 Part 3: Eye tracking and intertemporal choice

This was the main part of the experiment where participants' eye movements were measured by an eye tracker while they made a series of binary monetary intertemporal choices. There were 60 trials where they had to choose between a smaller-sooner (SS) and a larger-later option, similar to those of *Study 4*. However the delay of each option was accompanied by either an episodic tag or 'XXXXXXXX' as a visual control. This was placed just below the relevant delay and was registered as part of the delay attribute by the eye tracker. The crucial manipulation is study was the within-subjects manipulation *tagged vs. untagged*. This was operationalised by having 4 conditions (15 trials each): one in which the delays of both options were accompanied with episodic tags (*both tagged*), one in which neither option did (*none tagged*), one in which only the smaller-sooner option did (*SS tagged*) and one in which the larger-later option did (*LL tagged*).

Each of the trials were generated based on participants' k values from part 1, and episodic tags from part 2. The LL-amount (LLAMT) was drawn randomly from the range £100-£999, whereas the SS-amount (SSAMT) was based on the participants' discount rate, so choice task was set around their indifference point, according to their k value. The formula for this was: $SSAMT = LLAMT \times \left(\frac{(1 + k \times SSDEL)}{(1 + k \times LLDEL)}\right)$. The smaller-later amount was adjusted so that the smaller-sooner option more attractive in some trials, and the larger-later option more attractive in other trials.

SS-delays (SSDEL) and LL-delays (LLDEL) were in the cases of episodic tags obtained from the delays participants' chose for their tags, and for the non-tagged options delays were chosen from the following 7 ranges, but never the same as the delays chosen in the EFT-tag procedure: 2-4 days, 6-7 days, 3-7 weeks, 5-7 months, 10-14 months, 16-20 months, 22-26 months. When presented to the participants, all delays were written in number of days. Temporally adjacent delays, such as 2-4 days and 6-7, were not used to generate trials. From this there were a total of 60 possible combinations of tagged and un-tagged delays.

Additionally, there were 2 untagged catch trials, where there were a larger-sooner option that was clearly superior to the smaller-later option: £747 in 14 days vs. £290 in 65 days, and £457 in 36 days vs. £350 in 188 days. The six participants who failed one or two of these were excluded from the study as this suggested they were not paying attention. Consequently, there were 62 trials in total, and 54 remaining participants.

4.4.2.4 COUNTERBALANCING DESIGN

As with *Study 4*, choices for part 3 were either aligned vertically, with a left and a right option, or horizontally, with a top and a bottom option, showing either delays first or last, creating 4 possible alignments which were counterbalanced between participants (see section 4.3.2.4. for more details, as well as Figure 4.1). The order of the 62 intertemporal choice trials were randomised, as was order of the two options per trial. Crucially, there was also a within-participants manipulation: ¼ of the trials (15 trials) had episodic tags for: SS-delays, LL-delays, both delays, none of the delays. Illustrative examples of trials are shown in

Figure 4.9 (none-tagged), Figure 4.10 (SS-tagged) Figure 4.11 (LL-tagged) and Figure 4.12 (both tagged).

4.4.2.5 PROCEDURE

In the first part of the study, participants completed the ToAD on the questionnaire platform Qualtrics. The procedure generated a *k* value for the participant, which the experimenter copied and pasted into the Adobe Flash based episodic tag generating programme used in part 2 of the study.

In part 2, participants generated personal future events, similarly to the episodic future thought procedure of Study 2 and 3 in chapter 3. In turn, participants were asked to think of personal future events in 3 days, 1 week, 1 month, ½ year, 1 year, 1 ½ year, and 2 years from the present. These delays were also given in number of days. To keep things consistent with the procedure of studies 2 and 3, as these led to effective episodic tags, participants visualised these events for 30 seconds while a timer was displayed on screen, and they subsequently gave a brief description of at least 50 characters, along with a 4-15 character long label to be used as episodic tags in part 3 of this study. The programme generated the stimuli for the third part of the study, based on the *k* value of part 1, and the episodic tag and their associated delays, of part 2. The experimenter copied and pasted this output into a text file that would be read by E-prime in part 3.

The third and final part of the study was run on E-prime while using an eye tracker to record participants' eye movements as they complete the 62 intertemporal choice tasks outlined in the previous section. Before starting this task, the eye tracker was calibrated to best track the individual's eye movements as part of the E-prime experiment. Once the task was complete, participants were debriefed and paid for their participation.

4.4.3 RESULTS

Choice behaviour was measured as the proportion of larger-later choices for each of the four conditions: both options untagged, only the smaller-sooner option tagged, only the larger-later option tagged, both tagged. The means and standard deviations of these scores can be found in Table 4.11. The proportion of larger-later choices in each condition was compared against one another to see if people discounted less in one condition relative to the other.

Compared to the proportion of larger-later choices of .28 in the none tagged condition, there were .04 fewer larger-later choices in the smaller-sooner tagged condition, and this difference was significant, $t(53) = 2.182$, $p = .034$, $d = .297$. Compared to the none tagged condition, there were .10 more larger-later choices in the both tagged condition, $t(53) = 3.951$, $p < .001$, $d = .538$ (replicating Peters & Büchel, 2010), and .14 more larger-later choices in the larger-later tagged condition, $t(53) = 4.648$, $p < .001$, $d = .633$.

Compared to the smaller-sooner tagged condition there were .18 more larger-later choices in the larger-later tagged condition, $t(53) = 5.374$, $p < .001$, $d = .731$, and there were .14 more larger-later choices in the both tagged condition, $t(53) = 5.366$, $p < .001$, $d = .730$. While there were .04 more larger-later choices in the larger-later tagged condition than the both tagged condition, this difference was not significant, $p = .069$, $d = .252$. Table 4.10 from the rationale is reinstated here with p-values from the statistical analyses, highlighting which predictions were supported (see Table 4.12): Three confirmed hypotheses (H5a-c) supported both accounts, one (H4b) the episodic account and one (H3a) the attentional account .

Post-hoc power analyses were carried out on all of the six t-test above and found that four of them were well powered ($n = 60$, $\alpha = .05$, $1 - \beta = .972$-1), as opposed to the t-test comparing the none-tagged and smaller-sooner tagged conditions ($1 - \beta = .572$) and the t-test comparing the larger-later tagged and both-tagged conditions ($1 - \beta = .445$).

Table 4.11: Means (St.dev) for the proportion of larger-later choices per condition.

	None tagged	SS tagged	LL tagged	Both tagged
Larger-later choices	.28 (.04)	.24 (.04)	.42 (.05)	.38 (.04)

Note. Means (and standard deviations) for proportion of larger-later option choices for each of the four conditions. Higher numbers mean people discounted less.

Table 4.12: Predictions from Table 4.10, along with results from statistical analyses.

	None tagged	SS tagged	LL tagged
SS tagged	**SS*** / Same		
LL tagged	**LL****	**LL****	
Both tagged	Same / **LL****	**LL****	SS / Same

* = Significant at p <.05, ** = Significant at p <.001.

Note. Reinserting the overview of predictions from Table 4.10, along with results from the statistical analysis. The predictions supported by the statistical analyses are highlighted in bold. Where predictions differ between the two accounts, the prediction supported by the descriptive data is underlined.

In support of the attentional account, a smaller-sooner (SS) tag increased discounting (i.e., more SS-choices) relative to no tags, and in support of the episodic account, tagging both options reduced discounting (i.e., more LL-choices) relative to no tags. Also, in support of the episodic account, the data suggested there was no difference between tagging both options and the larger-later (LL) option only, but this did not reach statistical significance.

4.4.3.1 EYE MOVEMENTS

As with the previous study, the x and y coordinates of the eye movements were averaged across the two eyes and extracted into fixations and transitions as per the *R* package *Saccades*. For more details, see Study 4 in section 4.3.3.1. As with Study 4, fixations were explored both in absolute and proportionate terms for the 4 types of information on screen (section 4.4.3.2). Then fixations were used to count and categorise the transitions made between these 4 pieces of information (section 4.3.3.3) for each of the four conditions: none tagged, SS tagged, LL tagged, both tagged. Finally, eye movements were explored in terms of how well they could predict choice behaviour (sub section 4.3.3.4).

4.4.3.2 FIXATION DURATIONS

Table 4.10 and 4.11 shows the absolute and mean proportionate time spent looking at each of the 4 areas of interest per condition. The means show a greater fixation duration of 46 seconds in the both-tagged condition, than the 42-43 seconds in other conditions, and there was a main effect of tagging upon fixation duration, $F(3,159) = 3.621$, $p = .014$, $\eta_p^2 = .064$. Post hoc power analyses revealed this ANOVA to be well-powered ($n = 60$, $\alpha = .05$, $1 - \beta = .998$). The other post-hoc power analysis results are reported alongside the relevant comparisons that follow.

The 'both tagged' condition (46.0 sec) had significantly longer looking duration than the 'none tagged' condition (41.9 sec), $t(53) = -2.55$, $p = .014$, $d = .347$, $1 - \beta = .707$, and ' larger-later tagged' condition (42.2 sec), $t(53) = -3.23$, $p = 002$, $d = .440$, $1 - \beta = .888$. The greater fixation duration for the both-tagged condition relative to the 'smaller-sooner tagged' condition (43.0 sec) approached significance, $p = .69$. $d = .253$, $1 - \beta = .447$.

There was not significantly longer looking duration in the 'none tagged' condition relative to the 'smaller-sooner tagged' condition, $p = .469$, $d = .099$, $1 - \beta = .118$, nor the 'larger-later tagged' condition, $p = .993$, $d = .001$, $1 - \beta = .050$. There was also not significantly longer looking duration I the 'smaller-sooner tagged' condition than in the 'larger-later tagged' condition, $p = .359$, $d = .126$, $1 - \beta = .160$.

Table 4.13: Absolute means (St.dev) of fixation duration per condition.

	None tagged	SS tagged	LL tagged	Both tagged
SS delay	10.6 (5.4)	13.1 (7.2)	10.0 (6.0)	13.4 (7.5)
LL delay	11.6 (6.6)	11.1 (6.1)	13.2 (7.5)	13.2 (8.0)
SS amount	10.4 (5.4)	9.8 (5.2)	9.6 (5.3)	10.0 (4.7)
LL amount	9.3 (5.0)	9.1 (5.0)	9.2 (4.9)	9.4 (5.2)
Total	41.9 (20.0)	43.0 (21.2)	42.0 (20.1)	46.0 (22.3)

Note. Absolute means (standard deviations) of fixation duration (i.e., looking times) in seconds, for each option and attribute in each of the four conditions.

Table 4.14: Means (St.dev) for proportional fixation duration per condition.

	None tagged	SS tagged	LL tagged	Both tagged
SS delay	.257 (.064)	.305 (.089)	.242 (.065)	.292 (.070)
LL delay	.273 (.057)	.254 (.048)	. 308 (.071)	. 278 (.066)
SS amount	.249 (.052)	.229 (.059)	.232 (.067)	.228 (.073)
LL amount	.222 (0.65)	.212 (.082)	.218 (.066)	.202 (.065)

Note. Means (standard deviations) for proportion of fixation duration (i.e., looking times) at each option and attribute for each of the four conditions.

Conducting a similar analysis on proportionate rather than absolute looking times revealed a greater proportionate fixation duration times on delays when they are tagged (.28-.31) than when they were not tagged (.24-27). The same ANOVA could not be run as the sum of all proportionate looking times would add up to zero. So, in order to run t-tests to compare fixation durations for when delays were tagged and not tagged, two variables were generated.

[5] When comparing the two, there was significantly more looking at the larger-later delay when it was tagged (M = .586, SD = .127) than when it was not tagged (M = .526, SD = .093), $t(53) = -5.179$, $p < .001$, $d = .705$, $1 - \beta = .999$.

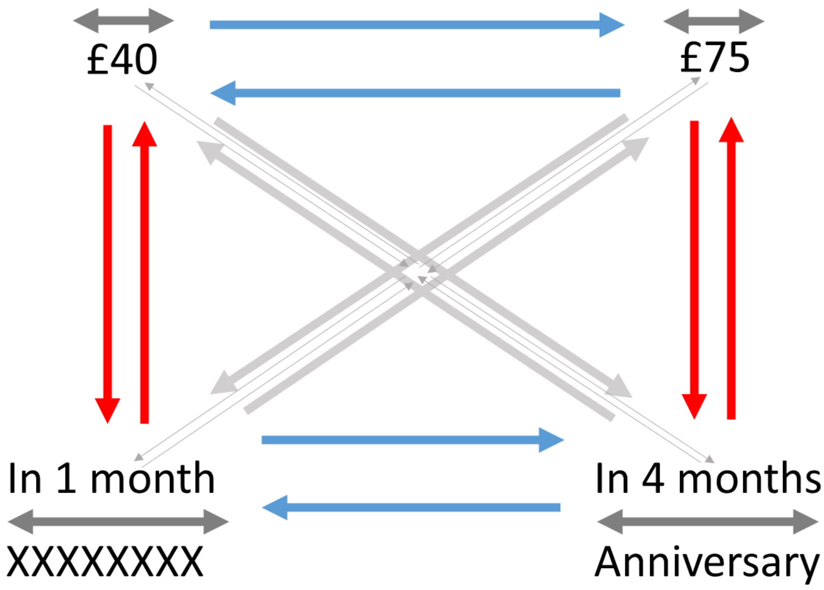
Likewise, a 'smaller-sooner untagged' variable was generated by adding the fixation durations on the smaller-sooner delay in the 'none tagged' condition and in the 'larger-later tagged' condition. Similarly, fixation durations on the smaller-sooner delay in the 'smaller-sooner tagged' condition and the 'both tagged' condition were combined into the variable 'smaller-sooner tagged'. Again, there was significantly more looking at the smaller-sooner delay when it was tagged ($M = .597$, $SD = .149$) than when it was not tagged ($M = .497$, $SD = .118$), $t(53) = -8.051$, $p < .001$, $d = 1.420$, $1 - \beta = 1$. Thus, overall people looked more at the delays when they were tagged than when they were not tagged.

4.4.3.3 TRANSITIONS

The same 16 transition categories of the previous study were extracted for each of the 4 conditions and are illustrated in Figure 4.8 . Only the red within-option transitions and the blue within-attribute transitions were included in the following analysis.

[5] First, a variable for when the larger-later delay was tagged was generated by adding together the fixation durations for the larger-later delays in the 'larger-later tagged' and 'both tagged' conditions. Second, the variable for when the larger-later delays was not tagged was generated by adding together the fixation duration times on the larger-later delays in the 'none tagged' and the 'smaller-sooner tagged' conditions.

Figure 4.8: An example trial showing the 24 transition categories.



Note. This is an example of the stimuli and its on-screen arrangement in a trial from the *larger-later tagged* condition. Note that this is not a screenshot, as the arrows are not visible to the participants. These arrows are added here in order to illustrate the different types of transitions referred to in this study.

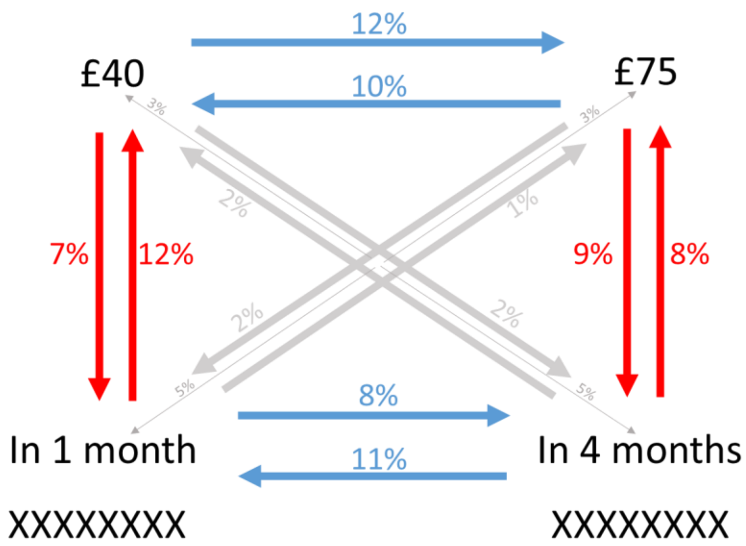
Blue arrows indicate within-attribute transitions and red arrows indicate within-option transitions. The four grey horizontal transitions represent the transitions made within each attribute, and the four grey diagonal transitions represent when participants transitioned across options and attributes (e.g., from the amount of one option to the delay of the other option). Lastly, the eight thin grey lines represent transitions between the fixation cross to either of the four attributes.

Table 4.15: Means (St.dev) for proportional transitions in 'none tagged' condition,

	SS AMT	SS DEL	LL AMT	LL DEL	FIX
SS AMT	-	**.07 (.03)**	**.12 (.04)**	.02 (.01)	.00 (.00)
SS DEL	**.12 (.04)**	-	.01 (.01)	**.08 (.03)**	.00 (.00)
LL AMT	**.10 (.05)**	.02 (.02)	-	**.09 (.03)**	.00 (.00)
LL DEL	.02 (.01)	**.11 (.04)**	**.08 (.03)**	-	.00 (.00)
FIX	.03 (.03)	.05 (.03)	.03 (.03)	.05 (.04)	-

Note. Means (standard deviations) for the proportion of transitions made between each attribute for the 'none tagged' condition. Fixations went from the attributes in the first column to the attributes in the first row. AMT = amount, DEL = delay, FIX = fixation cross, SS = smaller-sooner, LL = larger-later. The eight transition types of interest (4 within-option and 4 within-attribute) are highlighted in bold.

Figure 4.9: The means in table 4.15 that were greater than zero.



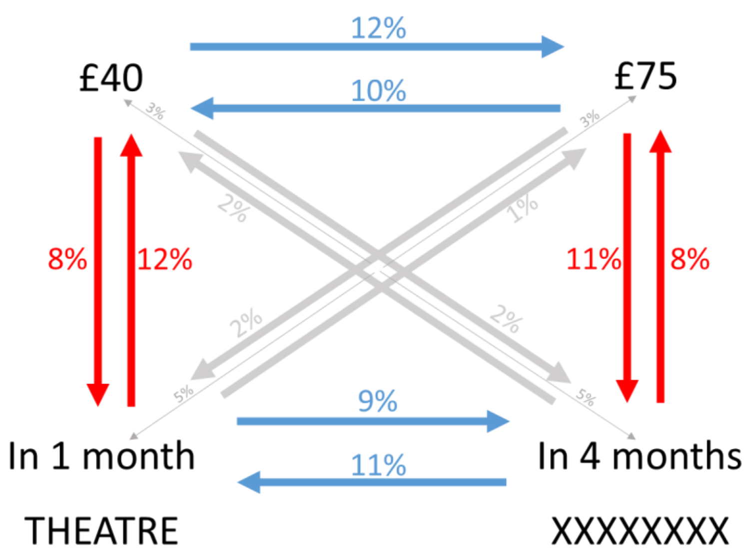
Note. The means for the proportion of transitions made between each attribute for the none tagged condition. Means smaller than 0% were excluded from this figure.

Table 4.16: Means (St.dev) for proportional transitions in 'SS tagged' condition

	SS AMT	SS DEL	LL AMT	LL DEL	FIX
SS AMT	-	**.08 (.03)**	**.12 (.04)**	.02 (.02)	.00 (.00)
SS DEL	**.12 (.05)**	-	.01 (.01)	**.08 (.03)**	.00 (.00)
LL AMT	**.10 (.05)**	.02 (.02)	-	**.09 (.04)**	.00 (.00)
LL DEL	.02 (.01)	**.11 (.05)**	**.08 (.04)**	-	.00 (.00)
FIX	.03 (.03)	.05 (.04)	.03 (.03)	.05 (.04)	-

Note. Means (standard deviations) for the proportion of transitions made between each attribute for the 'smaller sooner tagged' condition. Fixations went from the attributes in the first column to the attributes in the first row. AMT = amount, DEL = delay, FIX = fixation cross, SS = smaller-sooner, LL = larger-later. The eight transition types of interest (4 within-option and 4 within-attribute) are highlighted in bold.

Figure 4.10: The means in table 4.16 that were greater than zero.



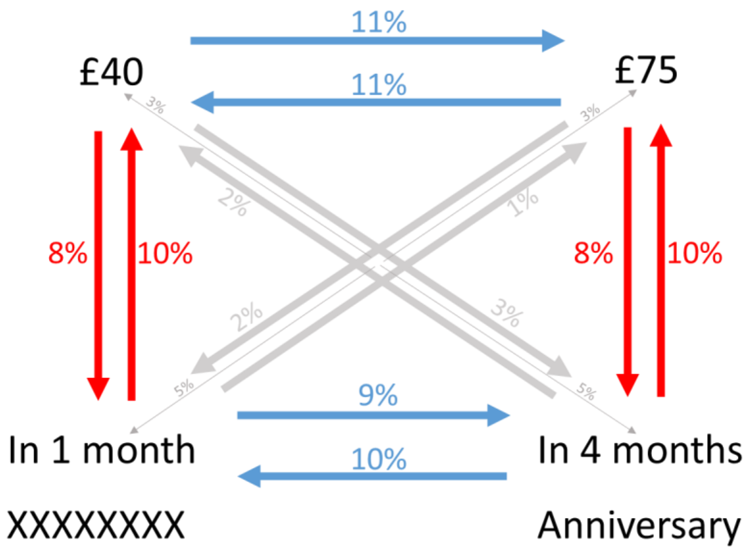
Note. The means for the proportion of transitions made between each attribute for the 'smaller sooner tagged' condition. Means smaller than 0% were excluded from this figure.

Table 4.17: Means (St.dev) for proportional transitions in the 'LL tagged' condition

	SS AMT	SS DEL	LL AMT	LL DEL	FIX
SS AMT	-	**.08 (.04)**	**.11 (.04)**	.03 (.02)	.00 (.00)
SS DEL	**.10 (.04)**	-	.01 (.01)	**.09 (.03)**	.00 (.00)
LL AMT	**.11 (.05)**	.02 (.02)	-	**.08 (.03)**	.00 (.00)
LL DEL	.02 (.02)	**.10 (.04)**	**.10 (.04)**	-	.00 (.00)
FIX	.03 (.03)	.05 (.03)	.03 (.03)	.05 (.04)	-

Note. Means (standard deviations) for the proportion of transitions made between each attribute for the 'larger later tagged' condition. Fixations went from the attributes in the first column to the attributes in the first row. AMT = amount, DEL = delay, FIX = fixation cross, SS = smaller-sooner, LL = larger-later. The eight transition types of interest (4 within-option and 4 within-attribute) are highlighted in bold.

Figure 4.11: The means in table 4.17 that were greater than zero.



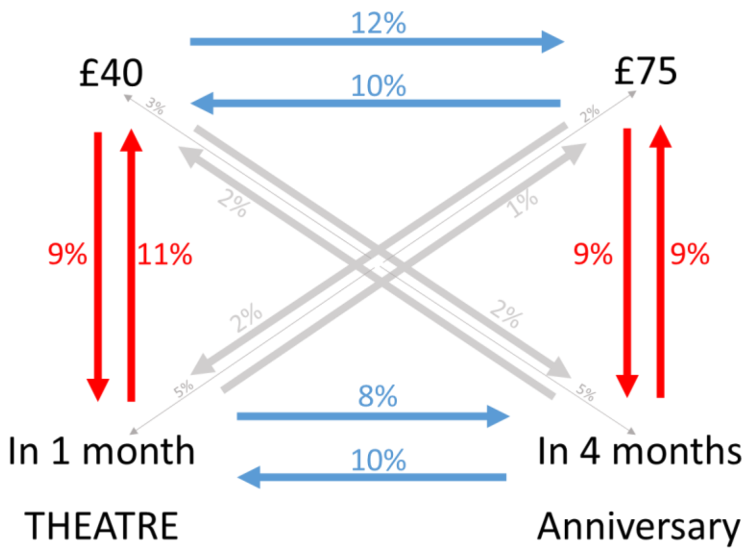
Note. The means for the proportion of transitions made between each attribute for the 'larger later tagged' condition. Means smaller than 0% were excluded from this figure.

Table 4.18: Means (St.dev) for proportional transitions in the 'both tagged' condition,

	SS AMT	SS DEL	LL AMT	LL DEL	FIX
SS AMT	-	**.09 (.04)**	**.12 (.04)**	.02 (.02)	.00 (.00)
SS DEL	**.11 (.04)**	-	.01 (.01)	**.08 (.04)**	.00 (.00)
LL AMT	**.10 (.04)**	.02 (.02)	-	**.09 (.04)**	.00 (.00)
LL DEL	.02 (.01)	**.10 (.04)**	**.09 (.03)**	-	.00 (.00)
FIX	.03 (.04)	.05 (.04)	.02 (.02)	.05 (.04)	-

Note. Means (standard deviations) for the proportion of transitions made between each attribute for the 'both tagged' condition. Fixations went from the attributes in the first column to the attributes in the first row. AMT = amount, DEL = delay, FIX = fixation cross, SS = smaller-sooner, LL = larger-later. The eight transition types of interest (4 within-option and 4 within-attribute) are highlighted in bold.

Figure 4.12: The means in table 4.18 that were greater than zero.



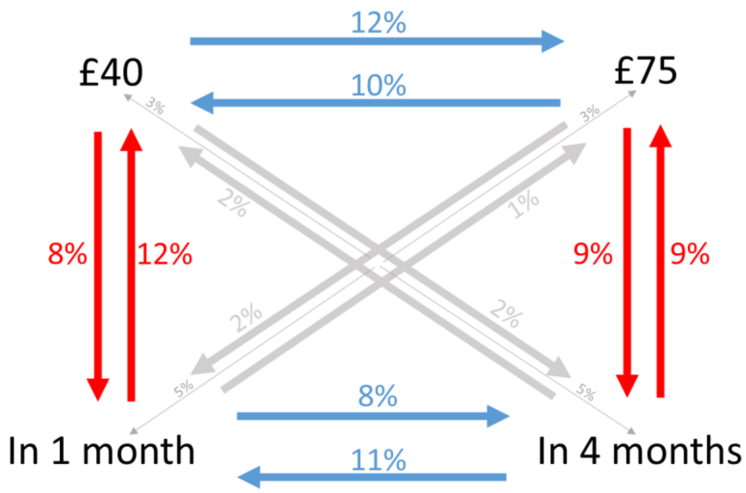
Note. These are the means for the proportion of transitions made between each attribute for the 'both tagged' condition. Means smaller than 0% were excluded from this figure.

Table 4.19: Means (St.dev) for the proportion of transitions across conditions

	SS AMT	SS DEL	LL AMT	LL DEL	FIX
SS AMT	-	**.08 (.03)**	**.12 (.04)**	.02 (.02)	.00 (.00)
SS DEL	**.12 (.04)**	-	.01 (.01)	**.08 (.03)**	.00 (.00)
LL AMT	**.10 (.05)**	.02 (.02)	-	**.09 (.03)**	.00 (.00)
LL DEL	.02 (.01)	**.11 (.04)**	**.09 (.04)**	-	.00 (.00)
FIX	.03 (.03)	.05 (.03)	.03 (.03)	.05 (.04)	-

Note. Means (standard deviations) for the proportion of transitions made between each attribute for all conditions collapsed. Fixations went from the attributes in the first column to the attributes in the first row. AMT = amount, DEL = delay, FIX = fixation cross, SS = smaller-sooner, LL = larger-later. The eight transition types of interest (4 within-option and 4 within-attribute) are highlighted in bold.

Figure 4.13: The means in table 4.19 that were greater than zero.



Note. These are the means for the proportion of transitions made between each attribute for all four conditions collapsed. Means smaller than 0% were excluded from this figure.

Table 4.15 shows the proportions of transitions made from one on-screen attribute to another for the 'none tagged' condition, and Figure 4.9 illustrate these transitions. Table 4.16 and Figure 4.10 do the same for the 'smaller-sooner tagged' condition, Table 4.17 and Figure 4.11 for the 'larger-later tagged' condition, Table 4.18 and Figure 4.12 for the 'both tagged condition', and lastly Table 4.19 and Figure 4.13 for all conditions collapsed. The table shows little to no fixations made from a particular attribute *to* the fixation cross, and the transitions made *from* a fixation cross to a particular attribute ranged from 2% to 5%. This likely reflected how the first transition in every trial is one that starts at the fixation cross. Moreover, transitions made diagonally, from one attribute to a *different* attribute of the other option only ranged between 1% to 3%.

That leaves the most meaningful transitions, which were the most common transitions made. Transitions made from an attribute in one option the other attribute in the same option (within-option transitions) ranged from 7-12%. Meanwhile, transitions made from one attribute to the same attribute of the other option (within-attribute transitions) ranged from 8%-12%. The Figures show somewhat fewer within-option transitions in the 'none tagged' and in the 'larger-later tagged' conditions relative to the 'smaller-sooner tagged' and the 'both tagged' conditions.

Table 4.20: Proportions of within-option transitions per condition.

	Within-option transitions means (st.dev)	None tagged p (d)	SS tagged p (d)	LL tagged p (d)
None tagged	.4609 (.0883)	-	-	-
SS tagged	.4766 (.1067)	**.04*** (.28)	-	-
LL tagged	.4596 (.1043)	.89 (.02)	.06 (.26)	-
Both tagged	.4849 (.0894)	**.01**** (.39)	.38 (.12)	**.01**** (.36)

* = Significant at $p < .05$, ** = significant at $p < .01$.

Note. Means (and standard deviations) for the proportion of within-option transitions, relative to within-attribute transitions, for each of the four conditions. All four conditions had more within-attribute than within-option transitions. In order of the least to most within-options transitions: ‘LL tagged’, ‘None tagged’, ‘SS tagged’, ‘Both tagged’. Statistical analyses showed that ‘Both tagged’ had only significantly more within-option transitions than ‘None tagged’ and ‘LL tagged’, and ‘SS tagged’ had significantly more within-option transitions than ‘None tagged’. Where the difference reached significance, at $p < .05$ and $p < .01$, the p-values are highlighted in bold.

The following six comparisons of the ratio of within-option and within-attribute transitions for each condition are reported along with post-hoc power analyses results. Although the means of the proportions of within-option transitions (relative to within-attribute transitions) appeared very close, as seen in Table 4.20, the none tagged condition had .016 fewer within-option transitions than the smaller-sooner tagged condition, $t(53) = -2.074$, $p = .043$, $d = .282$, $1 - \beta = .530$, and .024 more within-attribute transitions than the both tagged condition, $t(53) = -2.866$, $p = .006$, $d = .390$, $1 - \beta = .803$, confirming both hypotheses (H1a and H1d). There was also .025 more within-attribute transitions in the larger-later tagged condition than in the both tagged condition, $t(53) = -2.625$, $p = .011$, $d = .357$, $1 - \beta = .731$, also confirming the predictions (H1f).

While there were .017 more within-attribute transitions in the larger-later tagged condition than in the smaller-sooner tagged condition, this was only borderline significant, $p = .06$, $d = .264$, $1 - \beta = .478$ (rejecting H1c). There was no significant difference in type of transitions between the none tagged condition and the larger-later tagged condition, $p = .89$, $d = .020$, $1 - \beta = .052$,nor between the smaller-sooner tagged condition and the both-tagged condition, $p = .38$, $d = .119$, $1 - \beta = .138$ (rejecting H1b and H1e).

4.4.3.4 EYE MOVEMENTS PREDICTING CHOICE BEHAVOUR

The previous sections looked at what information participants look at when making intertemporal choices, regardless of what choices they made. This section explores the relationship between the measured mental processes and participants’ choice-behaviour.

Linear regressions were carried out for each of the four tag-conditions, and all analysis output can be found in Table 4.22 and Table 4.23 along with post-hoc power analyses. Descriptive statistics can be found in Table 4.21.

Correlations between the proportion of within-attribute transitions (relative to within-option transitions) and larger-later choices were much stronger for the none tagged, SS-tagged and LL-tagged conditions than the both-tagged condition. While the proportion of larger-later choices could not be predicted by the proportion of within-attribute transitions in the both-tagged condition(f^2 = .205) it did significantly predict more larger-later choices in the 'none tagged' condition(f^2 = .538) 'smaller-sooner' tagged condition (f^2 = .587) and the 'larger-later tagged' condition (f^2 = .389). Thus the a-priori hypotheses that more within-option transitions predicted more larger-later choices was rejected in favour of the predictions that follow form Study 4 for all but the both-tagged condiion.

As with the previous study, exploratory analyses were carried out to see which looking patterns could predict choice behaviour. Total looking time did not predict choice behaviour in neither the none tagged condition (f^2 = .176), the SS-tagged condition (f^2 = .282), the LL-tagged condition (f^2 = .220), nor the both-tagged condition (f^2 = .149). All of the above eight analyses were highly powered according to post-hoc power analyses.

Table 4.21: Descriptive statistics for merged variables.

	Prop. fixation on delays *(prop. SS delay + prop. LL delay)*				Prop. Fixation on LL option *(prop. LL amount + prop. LL delay)*			
	None tagged	SS-tagged	LL-tagged	Both tagged	None tagged	SS-tagged	LL-tagged	Both tagged
Mean	.529	.559	.550	.570	.495	.465	.526	.480
St.dev	.101	.114	.116	.119	.054	.061	.059	.056

Note. Means and standard deviations for proportionate fixation durations per option and attribute type. Here the proportionate fixation duration on each attribute were combined to create the following variables for each of the 4 conditions. The sum of proportionate fixation duration on SS (smaller-sooner) delays and LL (larger-later) delays formed the proportion of fixation duration on delays relative to the proportion of fixation duration on amounts. Likewise, the sum of proportionate fixation duration on LL amount and LL delay formed the proportion of fixation duration on the LL option relative to the SS option.

The proportions of delays were combined across options to explore whether looking proportionately more at delays relative to amounts would predict choice behaviour (see Table 4.21). Looking more at delays did not predict choice in the LL-tagged condition (f^2 = .282), but it did predict *fewer* larger-later choices in the 'none tagged' condition (f^2 = .639), 'smaller-sooner tagged' condition (f^2 = .786), and the 'both tagged' condition (f^2 = .389).

The proportions of fixation duration on larger-later attributes were combined to explore whether looking proportionately more at the larger-later option compared to the smaller-sooner would predict choice behaviour. Greater fixation duration on the larger-later option did not predict choice in the 'both tagged' condition (f^2 = .351), but it did predict more larger-later choices in the 'none tagged' condition (f^2 = .613*)*, the 'smaller-sooner-tagged' condition (f^2 = .818)and the 'larger-later tagged' condition (f^2 = 1.439). All of the above eight analyses were well-powered according to post-hoc power analyses.

Table 4.22: Predicting discounting with eye movements (EFT tags).

	F(1,52)	*p*	*r*	f^2	α	1- β
Prop. within-attribute transitions						
None tagged	**7.237**	**.01***	**.35**	**.538**	**.01**	**1**
SS tagged	**8.171**	**.006***	**.37**	**.587**	**.01**	**1**
LL tagged	**4.467**	**.039***	**.28**	**.389**	**.05**	**.994**
Both tagged	1.586	.214	.17	.205	.05	.904
Total fixation duration						
None tagged	1.138	.892	.15	.176	.05	.892
SS tagged	2.703	.981	.22	.282	.05	.981
LL tagged	**1.721**	**.046***	**.18**	**.220**	**.05**	**.946**
Both tagged	.870	.838	.13	.149	.05	.838
Prop. fixation on delays						
None tagged	**9.272**	**.004***	**.39**	**.639**	**.01**	**1**
SS tagged	**12.797**	**.001***	**.44**	**.786**	**.001**	**1**
LL tagged	2.700	.106	.22	.282	.05	.981
Both tagged	**4.315**	**.043***	**.28**	**.389**	**.05**	**.997**
Prop. fixation on LL option						
None tagged	**8.662**	**.005***	**.38**	**.613**	**.001**	**1**
SS tagged	**13.058**	**.001***	**.45**	**.818**	**.001**	**1**
LL tagged	**1.439**	**.000***	**.59**	**1.439**	**.001**	**1**
Both tagged	**.351**	.061	.26	.351	.05	.995

* = Significant at .001-.05 (see α in table)

Note. This table shows the statistical analysis for whether the following could predict proportion of LL-choices relative to SS-choices: within-attribute transitions, total fixation duration and proportionate fixation duration, for each of the four conditions.

SS = smaller-sooner, LL = larger-later, Prop. = proportionate (within-attribute transitions in proportion to within-option transitions, fixation on delays in proportion to fixation on amounts, and fixation on LL option in proportion to SS option).

Table 4.23: Descriptive statistics for proportionate fixation per attribute.

	Prop. fixation on LL delays				Prop. Fixation on LL amounts			
	None tagged	SS tagged	LL tagged	Both tagged	None tagged	SS tagged	LL tagged	Both tagged
Mean	.273	.254	.308	.278	.222	.212	.218	.202
St.dev	.057	.048	.072	.066	.065	.072	.066	.065

	Prop. fixation on SS delays				Prop. Fixation on SS amounts			
	None tagged	SS tagged	LL tagged	Both tagged	None tagged	SS tagged	LL tagged	Both tagged
Mean	.257	.305	.242	.292	.249	.230	.232	.228
St.dev	.064	.089	.065	.070	.052	.059	.067	.073

Note. Means and standard deviation for proportionate fixation duration per attribute, for each condition.

Finally, the proportion of looking at each of the four areas of interest was explored for their predictive ability of choice behaviour, as illustrated in Figure 4.14. Greater fixation duration on the larger-later delays did not predict choice behaviour for the none tagged condition (f^2 = .266), the SS-tagged condition (f^2 = .250), the LL-tagged condition (f^2 = .087), nor the both-tagged condition (f^2 = .408). However it is worth noting that the Pearson correlations for all but the LL-tagged condition pointed towards *fewer* larger-later choices with greater fixation duration for the larger-later delays.

Looking more at the larger-later amounts predicted *more* larger-later choices across all conditions: none tagged (f^2 = 1), SS-tagged (f^2 = 1), LL-tagged (f^2 = .786), and both-tagged (f^2 = .006). Conversely, looking more at the smaller-sooner delays predicted *fewer* larger-later choices across all conditions: none tagged (f^2 = .724), SS-tagged (f^2 = .852), LL-tagged (f^2 = .961), and both-tagged (f^2 = .493).

Lastly, fixation duration on smaller-sooner amounts did not predict choice behaviour in any of the conditions: none tagged (f^2 = .149), SS-tagged (f^2 = .299), LL-tagged (f^2 = .053, and both-tagged (f^2 = .136). Although it is worth noting that the Pearson correlation for all conditions but the LL-tagged condition pointed towards *more* larger-later choices with greater fixation durations on the smaller-sooner amounts. Thus, the trend overall was that looking more at delays led to fewer larger-later choices. Post-hoc power analyses showed that 14 of the above 16 regression analyses were well-powered. Only the analyses predicting choice-behaviour from the proportionate fixation on either the larger-later delay or the smaller-sooner amount in the 'larger-later tagged' condition were underpowered.

Table 4.24: Predicting discounting with eye movements (per attribute).

	$F(1,52)$	p	r	f^2	α	1- β
Prop. fixation on LL delay						
None tagged	2.420	.126	.21	.266	.05	.975
SS tagged	2.253	.139	.20	.250	.05	.968
LL tagged	.307	.582	.08	.087	.05	.613
Both tagged	1.144	.29	.15	.408	.05	.998
Prop. fixation on LL amount						
None tagged	**17.186**	**.001***	.50	**1.000**	**.001**	**1**
SS tagged	**18.780**	**.001***	.52	**1.083**	**.001**	**1**
LL tagged	**12.609**	**.001***	.44	**.786**	**.001**	**1**
Both tagged	**8.282**	**.001***	.37	**.006**	**.001**	**.091**
Prop. fixation on SS delay						
None tagged	**11.413**	**.001***	.42	**.724**	**.001**	**1**
SS tagged	**14.206**	**.001***	.46	**.852**	**.001**	**1**
LL tagged	**16.001**	**.001***	.49	**.961**	**.001**	**1**
Both tagged	**6.466**	**.01***	.33	**.493**	**.01**	**1**
Prop. fixation on SS amount						
None tagged	.877	.353	.13	.149	.05	.838
SS tagged	2.986	.090	.23	.299	.05	.986
LL tagged	.130	.720	.05	.053	.05	.416
Both tagged	.794	.377	.12	.136	.05	.803

* = Significant at .001-.01 (see α in table)

Note. This table shows the statistical analysis for whether proportionate fixation duration on either of the 4 attributes could predict proportion of LL-choices relative to SS-choices, in each of the four conditions.

SS = smaller-sooner, LL = larger-later, Prop. = proportionate (fixation on either attribute in proportion to the other three attributes).

Figure 4.14: Illustrating the fixation durations for the four conditions.

None tagged

£45 (+)	**£70 (+)**
3 days (-) **XXXXXXXX**	3 months (-) XXXXXXXX

SS tagged

£45 (+)	**£70 (+)**
3 days (-) **episodic tag**	3 months (-) XXXXXXXX

LL tagged

£45 (+)	**£70 (+)**
3 days (-) **XXXXXXXX**	3 months (-) episodic tag

Both tagged

£45 (+)	**£70 (+)**
3 days (-) **episodic tag**	3 months (-) episodic tag

Note. Participants looked more at the larger-later amount, highlighted in green, when making a larger-later choice, and they looked more at the smaller-sooner delay, highlighted in red, when making a smaller-sooner choice. Overall, this shows that participants looked more at the most desirable attribute (i.e., shorter delays and larger amounts) of the option they went on to choose in all four conditions.

4.4.4 DISCUSSION

This study sought to explore eye movements during conventional delay discounting tasks with or without episodic tags, as used in the study by Peters and Büchel (2010). As before, the aims were to compare the frequency of within-option transitions made compared to the number of within-attribute transitions. As per traditional discounting models, transitions within an option suggests a mental process in which people are weighing the outcome by the delay. Meanwhile, transitions from across options within attributes, as per more recent tradeoff models, imply a mental process in which options are compared along each attribute.

Another aim was to address a potential confound with the Peters and Büchel (2010) study, as the episodic effect may also be an attentional one where the tag reminding people of future plans simply draws more attention, rather than making people think episodically about the future. Hence, four different conditions were set up: 'none tagged', 'smaller sooner tagged', 'larger later tagged' and 'both tagged', indicating which option was accompanied by an episodic tag. As predicted by both the attentional and episodic effect, as well as replicating the findings by Peters and Büchel (2010), people discounted less when the larger-later option was accompanied by an episodic tag compared to when none of the options were episodically tagged.

In support of the episodic effect predictions, and contrary to the attentional account, there was less discounting when both options were tagged than when none were tagged. The attentional account would predict that attention would be evenly distributed between options either way, and so there should be no difference in discounting as a result of the episodic tags. However, the episodic account predicts that only the mental representation of the larger-later option can be changed with episodic tags, as the near future is already mentally represented more episodically. Moreover, the episodic account accurately predicted no difference in discounting between 'larger-later tagged' and 'both tagged' as the larger-later option is tagged in either scenario, and the added tag has no effect on the already episodic mental representation of the smaller-sooner option. These findings run counter to the attentional view that predicts more discounting when both are tagged as the smaller-sooner tag should draw attention away from the larger-later option.

Both accounts accurately predicted less discounting in the 'larger-later tagged' and the 'both tagged' conditions relative to the 'smaller-sooner tagged' condition for the same reasons as outlined above. The attentional account predicts less discounting because the attention is shifted from the smaller-sooner option to either the larger-later option (in the 'larger later tagged' condition) or to both of the options (in the 'both tagged' condition). Meanwhile the episodic account predicted less discounting because the episodic tag only has an effect on the larger-later option which reduces discounting.

The only finding that was consistent with the attentional view and counter to the episodic account was the increase in discounting when the smaller-sooner option was episodically tagged relative to when none of the options were tagged. A purely episodic view suggests there should be no difference as the smaller-sooner option is already mentally represented in an episodic manner. Although it is possible that the smaller-sooner option can be mentally represented even *more* episodically than it already is in terms of phenomenological qualities such as representation richness. There may be some attentional effects of the episodic tag as well, and this is supported by the significantly greater proportionate fixation duration when the larger-later delay was tagged than when it was not tagged, and when the smaller-sooner delay was tagged than when it was not tagged. Moreover, total fixation duration was greater for the 'both tagged' condition relative to the 'none tagged' condition and the 'larger-later tagged' condition.

As for eye movements, the a-priori prediction of this study mirrored that of the previous study. When dates were accompanied by episodic tags, the prediction was that there would be more within-option transitions as people mentally represent the time of receipt due to the episodic tag prompting episodic thinking (EFT). However, the findings in Study 4, along with the findings in Chapter 3 suggest another hypothesis. In Chapter 3, the interaction effect between the episodic tag effect and the date/delay effect suggested the two might be a result of the same underlying mental representation as there was no additive effect of the two. In Study 4, the date-condition had more within-attribute transitions than the conventional delay format (used in the present study). Thus if the two effects are caused by the same mental process, one might expect more within-attribute transitions for conditions with episodic tags as well.

However, the results were more in line with the a-priori hypothesis, where the 'both tagged' condition had significantly more within-option transitions than the 'none tagged' condition. The 'both tagged' condition also had significantly more within-option transitions than when only the larger-later option was tagged, and trending in the same direction for the smaller-sooner option, though not close to significance. There was no significant difference between 'larger-later tagged' and 'none tagged' or 'smaller-sooner' tagged. Overall, it appears that episodic tags lead to more within-option transitions than within-attribute transitions, reflecting how people create holistic episodic mental representation of the future option.

A series of analyses explored whether eye movements could predict choice behaviour. First, more within-attribute transitions predicted more larger-later choices in all of the conditions except for the 'both tagged' condition. A potential explanation for this is that episodic tags are harder to compare, but they still have an influence on choice (as evident from how 'both tagged' reduced discounting more relative to 'none tagged'). The episodic tags and are thus part of the mental representation of the two options in a manner that is less to do with how they compare and more to do with their episodic qualities.

Further exploratory analyses showed that total fixation duration did not predict choice in any of the four conditions. But when investigating whether people looked more at delays relative to amounts, looking more at delays predicted *fewer* larger-later choices in all of the conditions except for the 'larger-later tagged' condition. Moreover, when exploring whether looking more at the larger-later option relative to the smaller-sooner option, looking more at the larger-later option predicted *more* larger-later choices in all of the conditions except for the 'both tagged' condition. It is not clear why the 'both tagged' and the 'larger-later tagged' conditions differ on these predictive abilities, as the episodic account of the tag effect suggest the absence or presence of the episodic tag for the smaller-sooner delay should lead to little difference. Again, this suggests either some support to an attentional effect or that the smaller-sooner option can be construed in a more episodic manner than it is by default.

When looking at whether fixating more on each of the four areas of interest predicted choice behaviour, results were consistent across all four conditions: Looking more at the smaller-sooner delay predicted more smaller-sooner choices and looking more at the larger-later amount predicted more larger-later choices. Looking more at the smaller-sooner amount or the larger-later delay did not predict discounting behaviour. These findings fit with the idea of the gaze cascade effect, where people look progressively more at an option they ultimately prefer and choose but also tend to prefer and choose the option they look at more. The undesirable attribute did not show this pattern and that fits with the general idea of the gaze cascade effect.

The limitations of this study are the same ones as listed in Study 4. In short, the close to even split between within-attribute and within-option transitions may reflect people's preferred reading order from top left to top right to bottom right to bottom left, as this was counterbalanced across four conditions of the on-screen attribute layout. Moreover, the large number of trials may make participants shift their decision making strategies to one that lets them complete the series of relatively similar trials quickly. Thus, the processes involve may not capture the decision making processes used outside of the lab.

Overall, the findings support the idea that episodic tags make people shift their processing form relatively more within-attribute comparisons to more within-option comparisons, albeit modestly, as reflected by the eye movement transitions people made. This may reflect a shift of processing from comparing attributes across options to mentally representing each option in a more holistic episodic manner. Moreover, the episodic tagging effect was replicated and further supported as the effect remained when both options were episodically tagged. However, the effect went in the opposite direction, with more smaller-sooner choices when the smaller-sooner option was tagged, suggesting either that the tag also has an attention-grabbing component to it, or that the smaller-sooner option can be mentally represented in an even more episodic manner than it already is by default.

4.5 GENERAL DISCUSSION

These two studies were carried out to explore eye movements during intertemporal choice, specifically the fixation durations and the transitions made while completing a series of binary delay discounting tasks. In Study 4, participants' eye movements were recorded while completing delay discounting tasks in both the conventional delay-format (in number of months) and in the date-format (delays written as calendar months). In Study 5, there were four different between-subjects conditions of delay discounting tasks where none, both or one of the two options were accompanied by an episodic tag to remind the decision maker of their personal plans on the time of receipt. In 'none tagged' there were no episodic tags, in 'smaller-sooner tagged' there was an episodic tag adjacent to the smaller-sooner delay, in the 'larger-later tagged' there was an episodic tag adjacent to the larger-later delay, and in 'both tagged', both delays had an episodic tag each.

Study 4 successfully replicated the date/delay effect (Read et al., 2005) where people discount less when they see delays as calendar dates rather than as the conventional delay format. Equally, Study 5 successfully replicated the episodic tagging effect (Peters & Büchel, 2010) where people discount less when the larger-later delay is accompanied by episodic tags than when it is not. Moreover, this effect remained when both the smaller-sooner and larger-later delay was tagged, suggesting that the effect is truly episodic and not just an attentional effect. However, there was also more discounting when only the smaller-sooner delay was tagged, suggesting that there is either an attentional effect as well, or that the smaller-sooner option can be mentally represented in a more episodic manner than it is by default.

In Study 4, there was an even split between the number of within-option and within-attribute transitions made in the conventional delay format. This gives equal support to the traditional discounting models that describe delay discounting as weighing outcomes by their delays, and the more recent tradeoff based models where comparisons are made across options along each attribute. The integrational discounting models suggest people should look more within options as they weigh values by their respective delays, and the tradeoff models suggest people look more within attributes as they compare one outcome to the other and one delay to the other. The present results suggest people may use a combination of the two comparison strategies.

However, this even split between transition-types could be due to how people often read from top left to top right, then to bottom right to bottom left, which trends in the location-based transitions suggest. With the counterbalancing measure in place, this would appear to be an even split between the two types of transitions, making it appear that people use both comparison strategies. Meanwhile, in the date-format condition, participants made 57% within-attribute transitions, and this was largely reflected in greater fixation duration on delays in the date condition.

However, in Study 5, there was not an even split between the types of transitions, but rather 46% of within-option transitions were made in the 'none tagged' condition, which was the same as the 'delay-format' condition in Study 4. This might be the result of Study having the two delay-formats presented in counterbalanced blocks within-subjects, whereas in Study 5 the four conditions were randomised within-subjects. Thus, it is possible that the comparison strategies used in the four episodic tag-conditions carried over to one another more than the strategies used in the two blocked delay-format conditions.

While there were more within-attribute transitions for the date-format (57%; and 50% in the delay-format) in Study 5, Study 4 there were more within-option transitions when both delays were accompanied by episodic tags (49%) than when none were tagged (46%). These results are remarkable for two main reasons. First, Study 3 in this thesis found an interaction effect between the date/delay effect and the episodic tag effect. That is, there was no additional effect of episodic tags if delays were already written in calendar dates. This suggested that the effects may represent the same underlying mental representation. That is, episodic tags make people mentally represent the time of receipt episodically, and so does the date-format, leading to there not being any further attenuation of discounting when both conditions are met.

Second, both Study 4 and Study 5 predicted more within-option transitions when delays are tagged or in a date format. If the episodic tagging effect and date/delay effect are caused by people mentally representing the time of receipt in a more holistic episodic manner, this should be reflected in more within-option transitions as people form their mental representations. However, the relatively greater amount of within-option transitions when both delays are episodically tagged and the greater amount of within-attribute transitions when both delays are written in date-formats suggest different underlying processes.

The differences between transition-types for delay-format and episodic tagging could also be due to the different effect sizes of episodic tagging and the date/delay effect. The size of the effect of delay-format upon transition-type was large (d = .97), whereas the size of the effect of episodic tagging upon transition-type was on the smaller side (d = .28-39). Moreover, while the effect of delay-format upon transition-type had 0% chance of a type I error as well as a type II error, the tag-effect upon transition-type had 99-96% chance of a type I error and 47-20% chance of a type II error. Given the smaller effect size and statistical power of the tag-effect upon transition-type, this effect might be less meaningful than the effect of delay-format upon transition-type.

Eye tracking data across all conditions for both Study 4 and Study 5 were consistent: greater fixation duration on the smaller-sooner delay predicted more discounting whereas looking more at the large-later amount predicted more larger-later choices. Meanwhile, looking more at the more undesirable attributes, the smaller-sooner amount and the larger-later delay, did not predict choice behaviour. This is in line with the gaze cascade effect that shows a positive feedback loop where people progressively look more at what they prefer and ultimately choose, and also prefer and ultimately choose what they look at more.

4.5.1 LIMITATIONS

As with all eye tracking data, it is important to point out that not all eye movements directly map onto mental processing, but are rather a proxy of what people are attending to which in turn is a proxy of mental processes and representations. The relatively greater proportion of within-attribute transitions in the date-format relative to the conventional delay-format in Study 4 might simply be due to dates being harder to figure out temporally, and so people look at them for longer and this is reflected in more transitions between the two. Indeed, there was greater fixation durations on delays in the date-format condition but not in the delay-format condition. Moreover, the proportionate amount of within-attribute transitions only predicted more larger-later choices in the delay-format condition but not in the date-format condition, although there was both more larger-later choices and more within-attribute transitions in the date-format condition relative to the delay-format condition. Thus, it appears that the amount of within-attribute transitions due to greater fixation durations on delays do not reflect a shift on mental processing that have an effect on choice.

The sample sizes of Studies 4 and 5 were relatively smaller (N = 60 and 54) than Studies 1 and 2 (N = 313 and 117). However, much like Study 3 (N = 63) the results were meaningful and effects from the literature were replicated and expanded upon. Moreover, comparable eye-tracking studies in the judgement and decision making literature have successfully used similar participant counts or smaller, such as 48 participants in risky choice (Stewart et al., 2016a) and 32 participants in strategic choice (Stewart et al., 2016b). The sample sizes should therefore have been sufficient in size and quality for the present eye-tracking studies.

Another potential limitation of this study is that presenting participants with a series of choice tasks to complete may not accurately reflect the sort of decision-making processes that are used in day-to-day life. This is a potential problem with all multi-trial designs in decision making research where participants may adapt a decision-making strategy to efficiently let them make choices in order to get through the great number of trials quickly. One way to work around this issue would be to have only one or a small number of trials, but a greater number of participants. However, this is unrealistic in a lab study employing eye tracking equipment that needs to be calibrated and tried out before testing. Thus, an interesting follow-up study would be to have carry out a single-trial Mouselab based study online where many participants can be tested efficiently.

There is also a potential issue with participant's preferred reading order influencing the near even split between within-attribute and within-option transitions made. When observing the type of location-based transitions in Study 4, the descriptive date suggested that participants start by diverting their gaze from the central fixation cross to the upper left corner, to the upper right corner, to the bottom right corner and then to the bottom left corner. After counterbalancing for this by having delays either on top, bottom, to the left or to the right, this may appear as an even split when people might be making the same sort of transitions across trials. However, there were still differences between the conditions in Study 4 and Study 5 in terms of transition types, highlighting the importance of counterbalancing the on-screen attributes.

4.5.2 IMPLICATIONS

Overall, the results suggest that people make both attribute-based and option-based comparisons when making choices between smaller-sooner and larger-later options. Although both date-formats and episodically tagged larger-later options reduce discounting, people make more within-attribute transitions when delays are written as calendar dates, but they make within-option transitions when delays are episodically tagged. The episodic tagging effect appear to be an episodic rather than an attentional effect, as episodically tagging both delays reduce discounting, even though the tags demand the same amount of attention on both options.

4.6 OVERALL CONCLUSION

Both of these studies investigated eye movements in binary choices between hypothetical monetary smaller-sooner and larger-later options. The overall aim was to investigate whether people make more within-attribute transitions or more within-option transition, as a reflection of whether people make more comparisons within options or across options along each attribute. Traditional discounting models predict within-option transitions as people are described to weigh outcomes by delays, whereas more recent tradeoff models suggest that decision makers compare options along each attribute. The findings largely suggest that decision makers make both types of comparisons, as suggested by a near even split between the two types of transitions.

4.6.1 BEHAVIOURAL DATA

These two eye tracking studies each successfully replicated an established discounting attenuating effect from the intertemporal research literature. In Study 4, people discounted less when delays were written as the calendar date of the time of receipt than when they were written in the number of months to wait to that time. Study 5 Replicated the episodic tagging effect where people discount less when the episodic tag is accompanied by an episodic tag that reminds the decision maker of their personal plans at the time of receipt.

Moreover, this study demonstrated how the episodic tagging effect is not just caused by people attending more to the larger-later option due to the episodic tag. People still discounted less when the smaller-sooner *also* carried an episodic tag related to the decision maker's personal plans on *that* option's time of receipt as well, relative to when there were no episodic tags. However, participants discounted more when the smaller-sooner delay was episodically tagged and the larger-later delay was not, suggesting there might be an attentional component to the effect as well. However, it is also possible that the smaller-sooner option is not mentally represented fully episodically. That is, the episodic tag for the smaller-later delay may still make that option mentally represented in an even more episodic manner.

4.6.2 EYE MOVEMENTS

In Study 4, participants looked a lot more at the delays when they were written as dates, whereas they fixated equally on the four on-screen attributes for the conventional delay-format. A likely explanation for this is that dates are more difficult to compare to one another than delays, and so might require more mental processing. In turn, this greater amount of mental processing of dates was reflected in greater fixation durations for the date-formatted delays.

As for the transitions made, the delay-condition in Study 4 had an even split between the amount of within-attribute and within-option based transitions made. When viewing the delays as calendar dates however, participants made more within-attribute transitions, which could be a result of the aforementioned greater fixation duration on delay. That is, the greater mental processing of dates that is reflected in greater fixation durations of dates, consequentially leads to more transitions between dates as well.

Meanwhile, in Study 5, when both options were episodically tagged participants made more within-option transitions than within-attribute transitions. Thus, although the behavioural effect of both the date/delay effect and the episodic tagging effect are the same, as they both reduce discounting, they show different eye movements. This might reflect different underlying processes and mental representations, and is not something that could have been uncovered with purely behavioural measures alone.

4.6.3 EYE MOVEMENTS PREDICING CHOICE

Across all conditions in both studies, greater looking time at the larger-later amount predicted more larger-later choices, and looking more at the smaller-sooner delay predicted more smaller-sooner choices. This finding fits with the established gaze cascade effect where people progressively look more at what they prefer and prefer what they look at more. As for transition types predicting choice behaviour, the conventional delay-format in Study 4 and the 'none tagged', 'smaller-sooner tagged' and 'larger-later tagged' conditions in Study 5 predicted less discounting when people made more within-attribute transitions. Meanwhile, neither the date-format condition in Study 4 nor ‘both tagged’ condition in Study 5 could predict choice based on within-attribute transitions. Thus, it appears that while the date-format had more within-attribute transitions and the ‘both tagged’ condition had more within-option transitions, the proportion of transition types made did not predict choice behaviour.

4.6.4 CONCLUSION

In addition to successfully replicating and further supporting the date/delay effect and episodic tagging effect, the findings demonstrate the unique contribution of eye tracking technology in supplementing established behavioural findings. Although both effects show an attenuating of discounting, they show vastly different eye movements. Eye movements indicate what people overtly attend to as a proxy of what they are mentally processing and thus their mental representation. So, although calendar dates and episodic tags are similar in that they both reduce discounting, the mental representations that lead to these effects may be different.

5 CONCLUSION

The overall aim of this thesis has been to explore the mental representations and processes involved in intertemporal choice. Mental representations refer to how people cognitively symbolise external realities, be it in the past, present or future, and mental processes refer to what people *do*, cognitively, with these mental representations. Specific to this thesis, I have explored how people mentally represent the future when considering smaller-sooner and larger-later hypothetical monetary binary choices. Moreover, I have investigated what mental processes people employ when making comparisons between these options.

The research area of delay discounting often focuses a great deal on fitting choice data to various models of intertemporal choice. Arguably less research is dedicated to understanding, describing and explaining the psychological factors involved in intertemporal choice. However, some studies have found various contextual and procedural effects on discount rates, that are not predicted by any of the traditional discounting models.

A series of studies in the research literature have found that people discount less when engaging with episodic future thinking (Peters & Büchel, 2010; Benoit, Gilbert & Burgess, 2011; Cheng, Shein & Chiou, 2012; Liu et al., 2013; Lin & Epstein, 2014) and that manipulating construal levels can also alter discount rates (Malkoc & Zauberman, 2006; Malkoc, Zauberman & Bettman, 2010; Kim, Schnall & White, 2013). There is also a vast amount of unaccounted for variability in discount rates (Carter, Meyer & Huettel, 2010; Figner et al., 2010; Loewenstein, Rick & Cohen, 2008). I therefore wanted to explore whether some of the unexplained variability in discount rates could be accounted for by individual differences in episodic future thought and temporal construal. Research has also shown how people discount less when delays are written as specific calendar dates (Read et al., 2005), which seems a similar effect to that of how episodic future thinking reduces discounting. Thus, I wanted to see if there are any additive effects of episodic tags and date-formatted delays, or if these two effects are perhaps based on the same type of underlying mental representations. The first strand of research (Studies 1, 2 and 3) therefore focused on how the future is mentally represented, specifically focusing on episodic future thinking, temporal construal, and the date/delay effect, in relation to delay discounting.

The second strand of research (Studies 4 and 5) used eye tracking technology to explore what people looked at when choosing between smaller-sooner and larger-later options. Models of discounting can largely be grouped into two groups: traditional option-based discounting models, and more recent attribute-based discounting models. The option-based models assume that the decision maker considers each option in isolation, weighing the outcome by the delay, resulting in a discounted value. The option with the highest discounted value is then chosen. The weighing of outcome by delay would predict that people look more within each option, between outcome and delay, whereas attribute-based models predict that people look more from one option to another along each attribute. This is because attribute-based models assume people compare the delays directly, and the amounts directly. The eye tracker offers an opportunity to test these predictions directly, seeing people make more within-option or within-attribute fixation transitions.

In addition to testing the predictions made by option-based and attribute-based discounting models, I also wanted to explore the predictions of these in relation to the date/delay effect (Read et al., 2005) and the episodic tagging effect (Peters & Büchel, 2010). Findings from the first strand of research suggested shared underlying processes between the two effects, so I predicted that they would both lead to the same sort of comparison. Namely more option-based comparison, relative to more attribute-based comparison for untagged delay-format discounting trials, because people might form more holistic mental representations of each option, containing both the outcome and delay of that option. In addition to that, I wanted to give a general description of what attributes people look at the most, what comparisons they make, and whether these could predict choice behaviour.

Overall, the aim was to detail the mental representations and processes that take place when people consider whether to forgo greater future goods in exchange for immediate gratification. This final chapter of my thesis will describe the main findings across all five studies, the limitations of the studies and what possible future studies might be carried out to work around these limitations. Finally, I will discuss the implications and contribution of this thesis to delay discounting research and to the field of intertemporal choice.

5.1 MAIN FINDINGS

The main findings of this thesis are largely split into the two research strands, although some connections are made between the two when exploring the effects of episodic tagging and date format. I will first outline the key findings in this thesis, and then in each sub-section detail other findings for each of the two research strands. Across all of the first three studies, it appeared that the variability in individuals' discount rates could not be accounted for by individual differences in neither episodic future thinking nor temporal construal. Thus, even though both temporal construal and episodic future thinking influences discount rates, they do not appear to be the drive behind individual differences in discount rates.

For both eye tracking studies, people appeared to be employing a combination of attribute-based and option-based comparison strategies. People were looking roughly equally from option to option along each attribute, and from attribute to attribute within each option. However, it is possible that people were simply looking in a circle in their preferred reading order, from top-left to top-right and down and back up. Hence, a clear winner between traditional option-based discounting models and more recent attribute-based models cannot be named from these findings. However, the shift to more within-attribute comparisons when delays were written as dates, and to more within-option comparisons when delays were tagged suggest that what comparisons people do might depend on circumstantial comparison strategy choices.

5.1.1 STRAND I: MENTAL REPRESENTATIONS

Across the three first studies, people discounted values with delays, but the other two individual difference measures were more unstable across studies. The representation richness variable of EFT was only affected by delay in one of the three studies, and only the individual EFT phenomenology measures spatial context, emotional valence and personal importance were affected by delay across all three studies. Temporal context only decreased with delay in two of the studies. It is not clear why autonoetic consciousness, sensory detail, emotional experience, use of words and coherent experience did not show any effect of delay.

There was an effect of delay upon construal in only one out of three studies (though one bordered on significance, and the other had a lot of unclassifiable entries), suggesting that the effect of delay upon construal is not that powerful. Even though construal level was not much affected by delay, more high-level construals was associated with greater EFT representation richness. This is surprising, as EFT representation richness is largely described in a manner that resembles low-level construals more: more sensory, spatial and temporal detail. However, EFTs are also associated with elements resembling high-level construals: greater emotional valence, personal importance and coherent story.

Overall, there was no relationship between discounting and temporal construal nor between discounting and EFT, suggesting that individual differences in discount rates cannot be accounted for by individual differences in construal levels nor in EFT. The interaction effect between the episodic tagging effect and the date/delay effect is however interesting, as it suggests they might both reflect the same underlying mechanism in how we mentally represent the future. Together with the finding that individual differences in EFT and temporal construal level correlate weakly, it suggests that perhaps the three constructs are all, at least in part, different ways of capturing a single underlying variable. However, the present results can only support this claim modestly, due to the weak, if not absent, correlations between temporal construal and EFT.

5.1.2 STRAND 2: PROCESS TRACING

The first study replicated the date/delay effect, where people discount less when delays are written as calendar dates than conventional delays. People spent more overall looking time when delays were written as calendar dates, and most of that looking time was spent on the date-formatted delays. Similarly, the second study replicated the episodic tagging effect, where people discount less when delays are accompanied with reminders of their future plans. People spent more overall looking time when both delays were episodically tagged than when neither were, and most of the looking time was spent on the delays when they were tagged than not.

However, the difference between dates (relative to delays) and episodic tags (relative to no episodic tags) was in what comparisons people were making. People made more within-attribute comparisons when delays were written as dates, but they made more within-option comparisons when both delays were tagged, and more within-attribute comparisons when neither option were tagged.

The similarities between dates and episodic tags, or lack thereof, return when exploring whether within-attribute comparisons predict choice data. More within-attribute comparisons predicted less discounting when delays were *not* written as dates and when both delays were *not* tagged, and in the conditions where only one of the two options were episodically tagged. Hence, neither when both delays were written as calendar dates nor when they were accompanied by episodic tags did the proportion of within-attribute transitions predict discount rates. I will return to the similarities and dissimilarities between episodic tagging and date-format in the next section.

Finally, I explored whether the looking data could predict choice data. Across all conditions in both eye tracking studies, total looking time did not predict choice behaviour. Looking proportionately more at delays predicted more discounting for all conditions except for conventional delay formats and when only the larger-later option was episodically tagged. Looking more at the larger-later option predicted less discounting for all conditions except for when both options were episodically tagged. Finally, across all conditions in both studies, looking more at the larger-later amount predicted less discounting, and looking more at the smaller-sooner delay predicted more discounting.

5.1.3 ACROSS STRANDS

The main two aims of these studies were to explore if individual differences in construal levels and EFT could account for the unexplained variability in discount rates, and whether people make more within-attribute or within-option comparisons in discounting tasks. Although individual differences in discounting remain unaccounted for, and people appear to make an equal amount of within-option and within-attribute transitions, there were some interesting findings regarding mental representations across these studies.

To summarise, there was an interaction effect between the episodic tag effect and the date/delay effect, where there was no further additional attenuation of discounting when adding episodic tags to delays already written in a date format. This suggest that the two may both be part of the same underlying mechanism. Recall that people with greater high-level construals also had greater EFT representation richness, thus the date/delay effect, temporal construal and EFT may all be different approaches to capture the same underlying mechanism.

Considering that the episodic tagging effect and the date/delay effect may be part of the same underlying process, it is interesting that the eye tracker revealed categorically different comparison strategies for the two. When delays were written as dates, there was more within-attribute transitions compared to conventional delays. Meanwhile when both options were episodically tagged, where was more within-option transitions compared to when neither option was tagged. This shows the unique contribution of process tracing technology, such as eye tracking, as the behavioural data is rather similar, but the comparisons people make are different. However, it is possible that people were simply looking more at and between the dates because they are harder to compare, and not because they were necessarily comparing them more.

Even though there were less discounting and more within-attribute transitions when delays were written as dates, it was only for conventional delays that more within-attribute transitions predicted less discounting. This was also the case when delays were not episodically tagged, or only one of the options were episodically tagged. Thus, the ratio of within-attribute and within-option transitions for when both options are either written as calendar dates or episodically tagged does not predict whether people will discount more or less. Again, it might be that people were simply looking more at dates than delays because they are harder to work out. Thus, the greater number of transitions between the date-formatted delays may be no more meaningful than a reflection of looking more often at the date-formatted delays.

5.1.4 IMPACT OF RESEARCH ON THE FIELD

The research of this thesis highlights the role of mental representations and processes in intertemporal choice. With regards to mental representations, the interaction effect between the episodic tagging effect and the date/delay effect is interesting because it opens for the possibility that the two effects result from the same underlying mental representation of the future. Peters and Büchel (2010) argued in their paper on the episodic tagging effect that episodic tagging was not to do with what they called *date-based processing* in reference to the date/delay effect (Read et al., 2005). In support of this argument, they pointed to participants' self-report that they had processed the delays as delays and not as dates. They instead argued that the episodic tagging effect was due to a shift in temporal focus. However, the present finding that the date/delay effect and the episodic tagging effect interact, it might be that the date-formats and the episodic tags shift temporal focus in the same way, and effectively change mental representations in a manner that makes people value the future more. An alternative to this account would be that episodic tagging and the date/delay effect relies on separate mechanisms that for some reason cannot be used simultaneously.

Read and colleagues (2005) offered two explanations for the date/delay effect that fit with all of their experiments. First, the date-format may make people underestimate the length of the interval between the two points in time. Second, the two dates may feel more similar to the decision maker than two delays that are otherwise equivalent to the two dates. These two accounts do not really deal explicitly with mental representations. However, one could speculate that the date-frame might make the two points in time mentally represented more episodically, and thus judged to be more similar and closer in time due to greater representation richness from EFTs. Neuropsychological research shows that amnesic patients with no episodic memory or EFT discount relatively normally (Kwan et al., 2012), and so it would be interesting to see if they show the date/delay effect. If they do not show the date/delay effect, there would be further support that the episodic tagging effect and the date/delay effect are based on the same underlying mechanism.

As for the role of mental processes in intertemporal choice, the eye-tracking studies suggest people use a combination of attribute- and option-based comparisons. To recap, option-based discounting models like the DUM (Samuelson, 1937) and the HDM (Loewenstein & Prelec, 1992) have dominated the delay discounting research literature for longer, and predicts that people make more within-option comparisons. The more recent attribute-based models like the tradeoff (Scholten & Read, 2010), DRIFT (Read, Frederick & Scholten, 2013) and ITCH (Marzilli Ericson et al., 2015) models, however, predict that people make more within-attribute comparisons. Although the present data does not support one type of discounting model over the other, it does fit with more recent studies that shows the relationship between more within-attribute comparisons and less discounting (Reeck et al., 20017). Overall, this research highlights the importance of considering mental representations and processes in intertemporal choice, and should encourage future intertemporal choice research to incorporate these cognitive considerations.

5.2 LIMITATIONS

One particular limitation applied across all five studies was the use of a repeated delay discounting measure. Participants were asked to choose between a series of binary smaller-sooner versus larger-later monetary options. While this provides a rich data set from which to estimate discount rates, the sheer number of trials may lead to a different choice of strategy to what would be employed in everyday life. In turn, different choice strategies may mean people were generating different mental representation than to what they might form outside a lab or offline. In day-to-day life, people are more likely to encounter one-off decisions with real life incentives, instead of hypothetical rewards or secondary financial means even. They may be making intertemporal choices regarding more visceral stimuli such as food or addictive substances. Hence, there is a potential for poor ecological validity across all studies, and indeed across most conventional delay discounting studies that employ this 'smaller-sooner versus larger-later' methodology. Ideally, one would have been able to ask a very large pool of participants just one question each, but this is unrealistic in a laboratory setting over a restricted period of time.

Another potential limitation of these studies was to do with two of them being carried out online. When studies are carried out online, one cannot be sure that participants are fully devoted to the task with no distractions or concurrent activities. Study 1 and Study 2 of Chapter 3 focused on episodic future thinking and temporal construal in relation to delay discounting, and also in relation to the date/delay effect and episodic tagging in Study 2. However, in both of these studies, the established construal level measures used did not replicate. Only when employed offline in the lab, with only two delay variables to have more data points per variable, did the effect of delay on construal level replicate. The effect of delay upon valuation is a robust one and was successfully replicated across all studies, online and offline, as was the episodic tagging effect. The main struggle was to reproduce the predicted effects of delay on construal and episodic future thinking, suggesting that these measures are either not suitable for online surveys, or for individual differences. As mentioned in the

Chapter 3 discussion, the construal level measure is not normally used to measure individual differences, so it might simply not be appropriate for that objective.

With that being said, the particular issue of not being able to control the testing environments during online studies has been addressed by Crump, McDonnell and Gureckis (2013). They specifically looked at various well-established effects of cognitive behavioural experiments (e.g., the Stroop, Flanker and Posner Cuing) to see how they replicated online, using Amazon Mechanical Turk. Most of the tested effects replicated successfully (the exceptions were not particularly relevant to the present studies) and the authors recommended mTurk based cognitive behavioural studies should be considered a valid methodology, with the potential to produce high quality data.

Some caution was advised with regards keeping studies varied and engaging in to ensure participants' sustained attention and commitment in completing the study, and to ensure good comprehension of the task. Study 1 and 2 were varied with tasks that fell well within the recommended 5–30-minute range of the Crump et al. (2013) study, and the aforementioned replicated effects suggested good comprehension on the part of participants.

As for the eye tracking Studies 4 and 5, the predictions between traditional option-based models and more recent attribute-based models were of particular interest. The prediction was that greater within-attribute transitions would support attribute-based models, and greater within-option based transitions would support option-based models. To recap, option-based models describe how outcomes are weighted by delays for each option in isolation before the option with the greatest discounted value is chosen. Thus, these models predicted more within-option transitions, as people would have to make more within-option comparisons when weighing that option's value with its delay, and this should be reflected in greater within-option fixation transitions. Conversely, attribute-based models compare options directly along each attribute dimension, so that delays are compared with delays, and amounts are compared with amounts. This naturally predicts more within-attribute comparisons, which should be reflected in greater within-attribute fixation transitions.

However, as has been pointed out numerous times in the literature, attribute-based comparisons should be comparatively easier to do relative to option-based transitions (Payne, Bettman & Johnson, 1993). This makes intuitively more sense, as mentally weighing values by delays is harder than simply subtracting one delay from the other, or one amount from the other. However, if attribute-based comparisons are so easy, this may not require as much time. So even if people do rely on attribute-based comparisons, they may simply quickly, for instance, subtract £100 from £150, and subtract 10 days from 20 days. If they use a combination of attribute-based and option-based comparisons, as the fixation transitions in the data suggests, they will spend the remainder of the trial time on making within-option transitions. In other words, there is a possibility that within-attribute comparisons is not as easily captured by eye tracking data as within-option based comparison, as the difficulty level between the two differs.

Another related potential problem with the eye tracking studies is that the results may have been confounded by preferred reading looking order. The number of transitions made between various stimuli does support this suspicion, as there were more transitions from the initial central fixation cross to the upper left corner. And there were also a greater number of transitions from the upper left corner to the upper right corner, and from the upper right corner to the lower right corner. This suggests people may simply have been looking from the top left to the top right to the bottom right and to the bottom left. In this counterbalancing study this would have been evenly split between the stimuli, as they were counterbalanced in both top-bottom and left-right alignments. This could give the impression of an even split between within-attribute and within-option based transitions, but instead reflect what reading order people are used to. Some ways in which this could be examined will be discussed in the next sub-chapter.

5.3 FUTURE STUDIES

Some of the limitations above and in the relevant chapters can be addressed in future potential studies. Suggestions for these studies will be outlined in this section. A limitation that was brought up in the discussion of Chapter 3, was that the three measures of discounting, episodic future thinking and temporal construal were all looking at different items. In the discounting tasks, with or without the episodic tagging and/or the date/delay conditions, all trials concerned choices between smaller-sooner and larger-later hypothetical monetary options. However, the measurements for temporal construal and EFT focused on various actions, or specific events, respectively. The similarity between the objects in the EFT and temporal construal measures and their dissimilarity to monetary outcomes might be the reason only individual differences in EFT and temporal construal correlated. But here was no relationship between discounting with either EFT or temporal construal.

It would therefore be interesting for future work to examine the relationship between individual differences in discounting, EFT and temporal construal, in which the objects/events/stimuli of each measure are the same. On one hand, one might keep the design fairly similar to that of Study 1, 2 and 3, only ensuring that the items that are discounted, construed and represented as EFTs are the same sort of items (e.g., all monetary or all concrete events or material rewards). Alternatively, one might design an experiment in which the *same* exact stimuli is discounted, temporally construed and represented as EFTs.

The potential limitation that looking order being affected by preferred reading order is a concerning one that could be addressed in future studies as well. The main intent of such studies would be to further explore what comparisons people are making when choosing between smaller-sooner and larger-later monetary rewards. The present results suggested a near even split between within-attribute and within-option type comparisons, but it does not rule out that it is not just the same right-to-left and top-to-bottom reading order that is split evenly across counterbalancing conditions. Thus, the data could be analysed further, to compare the counterbalancing conditions that assigned people to horizontal and vertical choice matrices, could also shed light on whether fixations, transitions and even choices differed in these conditions.

Alternatively, two very different methodological approaches might help disambiguate the results. Although eye tracking technology has demonstratively, both in the present research and in the literature, given insight beyond what mere behavioural data can offer, other methodologies might also be suited. A different methodology to explore mental representations and processes is one that explores which attributes people remember from a conventional ‘smaller-sooner vs. larger-later’ delay discounting task. The aim is to see if people remember combinations of the same attributes more (e.g., the smaller-sooner amount and the larger-later amount) or less than the combined attributes for one specific option more (e.g., the smaller-sooner delay and amount). Participants would be presented with 4-6 trials of conventional delay discounting tasks, and in a later recognition task they would be asked to choose between combinations of attributes, selecting the ones they remember from the preceding delay discounting tasks.

If participants recognise more combinations of amounts than they do combinations of delays from a particular trial, this suggest they were making more attribute-level comparisons, thus supporting attribute-based discounting models. Conversely, if recognition is relatively greater for combinations of delays and amounts from within an option, this would suggest they were making option-level comparisons, supporting option-based discounting models. This could also be done with recall, asking participants to type in what other attributes they remember from the trial that had the “£20 sooner” attribute. In this example, if there is greater recall for the amount of the later option, than the delay of the sooner option, this suggest attribute-level comparisons were made in the preceding discounting task. If the opposite is true, this would support option-level comparisons, and thus option-based models. Thus, this innovative approach could shed light on the mental representations and processes involved in delay discounting from a different methodology.

The potential drawback of either the recognition version and certainly the recall version is greater working memory load, as people have to remember the attributes. Whereas in the eye tracking based studies in the studies of this thesis, people merely have to look at the attributes on screen. However, the two measures, eye tracking and memory, would supplement one another well. Should this strand of research also find an even split between attribute-based and option-based comparisons, there is further support that people use a combination of these comparison strategies in intertemporal binary choice. If considerably more within-attribute or within-option based combinations were remembered, it could mean that the even split between the two in these eye tracking studies are more to do with participants' preferred reading order, or indeed strategies employed due to the greater volume of trials.

Another idea for how to explore the role of within-attribute and within-option type comparisons is to manipulate what sort of comparisons make. Instead of, per trial, displaying both options with both delays and both amounts at once, the experiment could show these in a particular order. For instance, the order may be one that show the two amounts in order, and the two delays in order, prompting attribute-based comparisons. Or, the order may show the delays and amounts of one option first, and then the same for the other option. Memory load could be reduced by having these sequences looped until the participants makes a choice.

5.4 IMPLICATIONS

With this thesis I have sought to shift the focus away from the economics tradition of modelling intertemporal choice, towards a psychological exploration of what mental representations underlie intertemporal choice. Despite the numerous models developed to prescribe and describe discounting, there is a vast unaccounted-for heterogeneity in discount rates, and there is very little known about what mental representations and processes underly this. Two broad subjects from intertemporal choice research form the foundation of this thesis:

- The extent to which people discount the future can be influenced by how people mentally represent the future: episodic future thinking (e.g., Peters & Büchel, 2010), the date/delay effect (Read et al., 2005) and temporal construal (e.g., Malkoc et al., 2006, 2010). Thus, time preference depends on more than merely delay and value.
- The continuum of attribute-based and option-based (Payne, Bettman & Johnson, 1988) models of discounting (e.g., Loewenstein & Prelec, 1992; Scholten & Read, 2010). These suggest different comparison strategies that form different mental representations of options and their attributes.

These two subjects both hint towards what mental representations underlie intertemporal choice and might account for why people discount at such vastly different rates. However, in this thesis, individual differences in discount rates could not be accounted for by individual differences in episodic future thinking nor temporal construal levels nor in differing strategies for comparing options and attributes. This is the first study, to my knowledge, to employ measures of episodic future thinking and temporal construal in the same study, and the evidence suggested the two are related, as people with greater representation richness formed more high-level construals. Moreover, a key finding of this study was that the episodic-tagging effect and the date/delay effect did not lead to any further attenuation of discounting than either these effects on their own. This suggested that episodic future thinking and the date/delay effect are also related.

This forms the foundation for a more tentative claim of this study: that episodic future thinking, temporal construal and the date/delay effect are all different approaches to measure a single underlying variable. A variable that is the decision maker's mental representation of their personal future. For all intents and purposes, one might continue to call this variable 'episodic future thinking', as the date/delay effect does not have a definite theoretical explanation, and there are some problems with construal level theory. Although the evidence from this thesis supports this claim, some of this evidence is weak. The relationship between EFT and temporal construal was weak, and sometimes absent.

The difficulty in replicating the effect of delay upon construal poses some doubt for the construal level theory. If the effect only appears when the study is rigged in a very particular way, with great power in terms of many trials and few variables, and preferably in a lab setting, the effect may be overstated. In the literature I outlined some research that provided contrary findings despite exact replication of the studies, but only on different populations. Moreover, the theory could account for immoral behaviour being more or less frowned upon for the near and distant future, no matter the direction of the results. This difficulty in falsifying the theory, combined with the difficult in replicating the findings that founded the theory, with the same study design, is problematic for the validity of the theory as a whole. Given the correlation with episodic future thinking representation richness, it might simply be an ill-specified take on the underlying mental representation variable proposed earlier, that episodic future thinking is capturing better.

Another contribution of this thesis is the simplification of the episodic tagging procedure, which makes it more convenient to carry out online. These studies largely replicated the procedure by Peters and Büchel (2010), but instead of their elaborate interview procedure ahead of the discounting task procedure, we condensed this into a simple online survey. In this survey, participants imagined the future event at a given point in time, gave it a verbal name as an episodic tag, outlined a brief description, and rated it on various phenomenological scales (D'Argembeau & Van der Linden, 2004; 2006). The tags could then be retrieved from this procedure, along with discount rates from a discounting calibration procedure, and applied to the appropriate delays in a discounting task. This simplification of the Peters and Büchel (2010) methodology means that the episodic-tagging effect on discounting can be explored further with greater ease, more participants and online.

A finding that complicates the proposal that episodic future thinking, temporal construal and the date/delay effect are all related to the same underlying mental representation variable, is that the eye tracking data revealed different comparison strategies for dates and episodic tags. This highlights the unique contribution of eye movement measurements that cannot be derived from choice data alone. Both the date/delay effect and the episodic tagging effect reduce discounting, and the two appear to be based on a shared underlying mechanism as there is no benefit to employing both simultaneously. I suggest that the date/delay effect and the episodic tagging effect are the same, but that they lead to different comparisons. These comparisons may be a reflection how it is more difficult to compare delays, rather than any differences in how people mentally represent the future.

Finally, this is the first study using eye tracking technology to compare the predictions of option-based and attribute-based discounting models. Traditional option-based discounting models predict more option-based comparisons whereas more recent attribute-based discounting models predict more attribute-based comparisons. However, the fixation transition data in the present research suggest that people do a combination of both. This is the first time, to my knowledge this has been researched by directly tracing peoples processing by means of eye tracking in conventional smaller-sooner vs larger-later discounting tasks. Some suggestions for future studies were made in the previous section, to investigate whether people are truly using a combination of the two comparison strategies or if looking order reflects reading order more than it reflect mental processing and comparisons.

To conclude, I believe that researching and theorising on delay discounting and construal level theory in intertemporal choice, episodic future thinking in memory research is an interesting intersection of research that may illuminate why people discount so differently. I hope this thesis contributes to and encourages more research on how people think about and mentally represent their personal future and how this influence their intertemporal choice. The more we know about how people mentally represent the future, and specifically how to make them think about the future in a way that reduce discounting, the better equipped we are to implement what we know to make people make more longsighted decisions, such as saving for their pensions.

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