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Discrimination Problems in Context-Dependent Memory

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Declaration

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Abstract & Foreword

This thesis investigates the validity of a view of memory retrieval that insists on the diagnostic relationship between a target memory and a retrieval cue. The widely accepted principle of encoding-retrieval match proposes that retrieval performance is related to the degree to which the cues at the time of retrieval are compatible with those at the time of encoding (Tulving, 1979, 1983). The effect of cue-overload, another well-documented effect, stipulates that memory retrieval performance is expected to decrease as the number of potential targets in memory subsumed under a retrieval cue increases (Watkins & Watkins, 1975). With these two effects interacting, a variety of outcomes are possible. The memory as discrimination view investigated as part of this thesis suggests that factors such as cue-overload, distinctiveness, context, and potentially others contribute to a process of memory retrieval where diagnosticity is central (Nairne, 2002). Under such a view encoding-retrieval match cannot be relied upon to generate predictions. Under a diagnostic retrieval system, retrieval is most likely to be successful when a cue specifies a target in memory while excluding other potential candidates. Other memory as discrimination views do exist. However, within this thesis the above view is the only one being considered.

The studies presented as part of this thesis investigate the memory as discrimination hypothesis by studying the interaction between cue-overload and encoding-retrieval match. Empirical investigations are included in which proportion of correct responses is considered. More formal work is also included in which response

time and probability of correct recall data are called upon. Chapter 1 reviews the relevant literature in the field, while chapters 2 and 3 report empirical investigations testing the predictions of the memory as discrimination hypothesis. In chapters 2 and 3, paired associate learning tasks were used. In such a task, participants are presented with pairs of words under the instruction that they will later be asked to remember one member of a given pair using the other member as a retrieval cue. Chapters 2 and 3 present the results of studies where the encoding context was manipulated to investigate the roles of encoding-retrieval match and cue-overload in retrieval. This was achieved by using contexts that were unique to a target or associated with multiple targets and then orthogonally manipulating encoding-retrieval match and cue-overload. The experiments reported in chapter 2 used interactive contexts in the form of spot the difference images; participants were asked to spot the difference between two images; each time they were successful, they were provided a pair of words to associate. Cue-overload was manipulated by varying the number of word pairs associated with a given spot the difference image. At test, the first word of each pair was presented and participants were required to provide the correct second item. The reinstatement or non-reinstatement of the background images at test was employed as a means of manipulating encoding-retrieval match. Using fonts as context, the experiments reported in chapter 3 varied the number of word pairs per list that shared a font, and manipulated the reinstatement of originally viewed fonts to further test the findings of chapter two. The general prediction of the memory as discrimination view across experiments in chapters 2 and 3 is that a reduction in the level of encoding-retrieval match between conditions may result in a detrimental, null, or beneficial effect on retrieval performance depending on the presence of a cue-overload effect.

Chapters 4 and 5 offer mathematical representations of cue-overload, encoding-retrieval match, and possible interactions between the two in accordance with a memory as discrimination view. The predictions from these formal representations are qualitatively compared to the data from experiments that manipulated encoding-retrieval match and cue-overload. Formal representations of encoding-retrieval match and cue-overload in chapter 4 predict the contributions of encoding-retrieval match and cue-overload in response time. A formal model of the probability of correct retrieval is offered in chapter 5. The essential feature of the model presented in chapter 5 is in its generation of predictions in which the effect of encoding-retrieval match can be reversed by changes in cue-overload. The present thesis concludes that the effect of encoding-retrieval match is highly dependent on cue-overload in several ways and can be seen as unreliable – and further, that context cues may serve to facilitate this dependence.

Chapter 1:

General Introduction

In the following pages, the main concepts relating to encoding-retrieval match and cue-overload will be introduced and the key studies in the field will be reviewed. This includes the main concepts relating to the memory as discrimination view, namely that that memory retrieval performance is related to the degree to which a retrieval cue specifies a single memory for retrieval to the exclusion of all others. This brief review highlights the implications of the memory as discrimination view and provides the background to the empirical and more formal chapters that follow. Without being exhaustive, the literature review concentrates on a number of seminal contributions, ideas and findings that were instrumental in establishing some of the core principles typically associated with memory retrieval.

1.1: *Encoding-specificity*

First proposed by Tulving and Osler in 1968, the encoding-specificity principle states that a retrieval cue can only be effective if it was part of the original encoding (e.g. Tulving & Osler, 1968; Tulving & Psotka, 1971). This principle continues to be influential in memory research (Braisby & Gellatly, 2005). Encoding-specificity rests at the very core of this thesis in that the concepts under investigation (encoding-retrieval match, cue-overload, and memory as discrimination) all rely on encoding-specificity (Nairne, 2002). This section of the thesis concentrates on the history of encoding-specificity from the research climate during the 1960s to the research papers introducing it. In this way a more thorough picture of the relationship between encoding-specificity, encoding-retrieval match and cue-overload may be established in subsequent sections of the thesis.

Although much earlier work on memory of course existed (e.g. Ebbinghaus, 1885/1913; McGeoch, 1932; von Restorff, 1933), interest in the subject did not bloom until the 1960s, when research into the processing and organization of memory was a very new field. During the 1960s a great deal of research centred on answering the question 'what has become of those things we have forgotten?' Trace decay theory was among the more popular modes of explaining why memories may be inaccessible at the time of retrieval (e.g. Brown, 1958), essentially suggesting that over time memories lose those features which compose their details, eventually making those memories unavailable or completely lost. Memory displacement was another possibility under investigation during that time (Waugh & Norman, 1965). Under a displacement view of forgetting, previously learned items are relocated in the memory system when new items are stored, thus making them unavailable. In the case of either a decay or a displacement theory of forgetting, the memory trace can be seen as being unavailable at the time of attempted retrieval (Tulving & Pearlstone, 1966). By unavailable it is meant that the memory trace cannot (or may never be) retrieved in its original form - as opposed to it being momentarily inaccessible, but potentially available given an appropriate retrieval cue. At the time of Tulving and Pearlstone's article the decay and displacement theories of forgetting were considered applicable to long-term memory (see Tulving & Pearlstone, 1966). However, the current view is that there is little support for a decay theory of forgetting (e.g. Capaldi & Neath, 1995; Eysenck & Keane, 1995). A model in contrast to this line of thought was Feigenbaum's (1961) information-processing model, which provided the hypothesis that at the time of attempted retrieval the memory may be available, but inaccessible due to the memory system's inability to locate it in a vast and growing network of memories (Tulving & Pearlstone, 1966). It was Feigenbaum's (1961) view that Tulving and colleagues (beginning with Tulving & Pearlstone, 1966) investigated and ultimately championed.

Tulving and Pearlstone (1966) reported an experiment in which participants learned categorized words in lists. The list length (12, 24 & 48 items) and number of items per category (1, 2 & 4) were manipulated as well as the type of retrieval cue used at testing. When tested participants were either asked to write down as many words as they could remember (free recall), or were cued by the names of the categories used in the list. This experiment was testing the hypothesis that having a cue could empower participants to remember something that they would not otherwise have remembered; this would be in line with the idea memories may be available without being accessible until a cue is presented (e.g. Capaldi & Neath, 1995; McGeoch, 1932). Tulving and Pearlstone (1966) supported this view as their data indicated that recall was better with category-cues than without. The manipulations of list length and number of items per category demonstrated that the size of the effect of test type (cued versus free recall) was related to list length by an increasing function and to the number of items per category by a decreasing function. As the lists became longer, the amount of assistance participants received from cues increased; in other words, all else being equal, the longer the list the bigger the difference between cued and non-cued recall. Also, the data of Tulving and Pearlstone (1966) indicated that a category cue for a category containing few items is more likely to retrieve those items than a category cue for a category containing several. Such results supported a view stating that a cue supports retrieval based on the degree to which a memory is specified by the cue. After all, a category cue for a category with one member specifies a candidate for memory retrieval to a greater degree than a category cue for a category with four members.

Results arising from earlier studies (e.g. Mandler, 1967; Melton, 1963; Tulving & Pearlstone, 1966) allowed Tulving and Osler (1968) to begin with an assumption: that successful retrieval depends on the availability of items in memory *and* the availability of appropriate retrieval cues at the time of attempted retrieval. At this time the most widely recognized views of remembering concerned an associative continuity hypothesis, originally offered by Fox, Blick, and Bilodeau (1964), by which to-be-remembered items are stored in memory in such a way that they are connected to other memories containing features commonly associated with the features of the to-be-remembered item. In this way, under an associative continuity hypothesis, memories may be retrieved by associates even if those associates were not present at the time of memory encoding. Tulving and Osler designed an experiment to answer four very specific questions (paraphrased from Tulving & Osler): 1) can words be cued successfully for recall using only another, weakly associated word? 2) Can a retrieval cue that would be effective if presented both at the time of learning and the time of testing be effective if it is only presented at the time of testing? 3) If a word presented at the time of learning would be effective as a retrieval cue at the time of testing, would a similar replacement word be equally effective? 4) Are two equally well associated retrieval cues better than one?

These questions were designed to shed light on the subject of memory retrieval and composition of effective retrieval cues. Tulving and Osler (1968) presented lists of

24 words to participants. The words were either presented with no cue word, with a weak associate, or with two weak associates. At test, participants were either provided with a weak associate, with both weak associates, or were asked to recall as many words and cues as possible in free recall. The results of Tulving and Osler indicate that weak associates may be effective as cues when presented with the target word at both learning and test but not when they are only presented at test. The use of an alternate associate at test was also shown to be detrimental. Two associates were not shown to be better than one. The Tulving and Osler data suggested that retrieval cues are only effective if they are stored with the to-be-remembered item at the time of learning (in the case of explicit, episodic memory) because only those associates which had been presented during the learning phase were effective. The data indicating that alternative associates presented at test were less effective in retrieving the appropriate target than free recall suggested that these cues were retrieving items from outside of the list. Two cues not being more effective than one may have shown reliance on one of the cues that had been presented during the learning phase, with the other being superfluous. In this regard, the evidence suggested that when a new memory is formed it is not associated to memories outside of the episode in which it is established --except what might be brought to mind by within episode retrieval-- even if it could be logically expected that associations would form by virtue of the relevant concepts being similar, used in like circumstances, *etc.*

This led Tulving and Osler to define encoding-specificity as the effect by which memories can only be retrieved *via* retrieval cues that were part of the episode in which the memories were encoded. These results conform to what would be expected following altered context or altered stimulus conditions (McGeoch, 1932) - A retrieval cue, presented in a situation differing from the original learned episode, may not be expected to elicit the same result. However, an important distinction relates to what are known as nominal and functional cues. A retrieval cue *seen* as being important by the experimenter can only be considered a nominal retrieval cue as all of the cues present at the point of encoding will determine what the main features of the memory will be. The environment and target items can be considered the functional retrieval cue (Capaldi & Neath, 1995; Neath, 1998; Postman, Stark & Fraser, 1968).

Tulving and Osler's (1968) paper was met with 'vehement objections' when reviewed for publication. These criticisms centred on the implication raised by Tulving and Osler's results that "...participants' pre-experimental histories cannot be effectively utilized [by experimenters]..." (Thomson & Tulving [1970, page 255] quoting an anonymous reviewer). Thomson and Tulving responded directly to this criticism by investigating the role of strong pre-experimental associates in the paradigm utilized by Tulving and Osler (1968). Across three experiments –words were either presented alone, with a weak associate, or with a strong associate, then later tested either with free recall, with the same weak associate, or with a different associate (weak and strong being swapped). The results indicated that strong pre-experimental associates did not facilitate retrieval of the target word unless that associate had been presented with the word in the learning phase. However, when a strong associate had been presented at both learning and testing, that condition resulted in greater retrieval performance than the condition in which participants had been provided a weak associate at both learning and testing. This lead Thomson and Tulving to conclude that although the encoding-specificity principle was supported by the results, pre-experimental associations were useful in facilitating greater retrieval performance when those associates were presented at both learning and testing.

While responding to proponents of the associative continuity hypothesis Tulving and colleagues placed encoding-specificity in a category of hypotheses attempting to explain the effectiveness of extra-list retrieval cues. Tulving and Thomson (1973) present encoding-specificity as an explanation for the lack of effectiveness of strong pre-experimental associates as retrieval cues in contrast to other theories from the literature of the time. Tulving and Thomson's proposal was that not only is encoding-specificity the only explanation for the superiority of weak associates presented during learning and testing over strong associates only presented at test, but also the best explanation for the superiority of strong associates over weak associates when both are presented at learning and testing. At the time, other hypotheses attempting to explain the effectiveness of various cues (as introduced in Tulving and Thomson, 1973) included: 1) Convergence of episodic and semantic associations: Under this view the experimental context present at both learning and testing acts as one cue while pre-experimental associations act as another; the combination of these two allows for a greater probability of recall than either experimental context alone (free recall) or that plus a weak associate (Bilodeau, 1967; Bilodeau & Blick, 1965) 2) Increments in trace strength: this view suggests that pre-experimental associates are associated because they occurred together repeatedly. Repeated cueing of items increases their 'trace strength,' and as such pre-experimental associates have similar trace strength from having been cued together previously (Broadbent, 1973); 3) Restricted search set: Cueing creates a search set through which items are added via their associations to one another, not just the cue. The assumption is that the search set in recognition is smaller than that in recall (Atkinson & Shiffrin, 1968; Yntema & Trask, 1963). 4) Mediation by input-generated implicit associative processes: pre-experimental associations are updated during the experiment (Freund & Underwood, 1970). In this way, when a pair of associates is presented at the time of learning both members of the pair naturally cue related items in memory. When the first member of a pair is read an implicit response is activated in the participant and some (probably strong) associates are brought to mind. These input-generated, implicit, associative processes are more likely to coincide with a strong associate being paired with the word at learning than a weak associate. 5) Generate–recognize: A two stage view in which there is implicit generation of possible response alternatives and recognition of one of the generated alternatives as meeting certain criteria of acceptability. In this way recall will be a subset of the items available for recognition (e.g. Mandler, 1972). According to Tulving and Thomson the most popular views for explaining recognition and recall of the time were the generate-recognize models. An essential prediction of these models was that because recall happens within the confines of recognition, recall performance cannot exceed that of recognition performance on the same material. Tulving and Thomson (1973) challenged the generate-recognize model by challenging this prediction and providing data explainable through encoding-specificity alone.

In Tulving and Thomson (1973) participants were presented with paired associates to learn. Then they were asked to produce free association responses to strong extra-list associates of the target words from the list. They were then asked to identify those items in their associations that had been in the to-be-remembered list. Participants were then administered a cued-recall test using the associates originally presented as retrieval cues. Across three experiments Tulving and Thomson presented results in which the paired associate presented at the time of learning elicited a greater proportion of correct responses than did a copy of the target (i.e. recognition). Following a criticism by Santa and Lamwers (1974) that the participants in Tulving and Thomson's (1973) experiments were confused, Tulving and Thomson's experiments were replicated in Wiseman and Tulving (1975) controlling for participants' familiarity with the task requirements. Wiseman and Tulving (1975) were able to demonstrate a similar pattern of results to Tulving and Thomson (1973) after having adjusted the task to avoid confusion. Additional criticisms were in the form of suggesting that participants do not actually recall what they fail to recognize, they simply have a higher proportion of recalled words than recognized words and that the words recalled were not words that went unrecognized. This too was addressed in Wiseman and Tulving (1975) in that the authors report the conditional probability of a word being recalled but not recognized as being 36% in a given list. The series of findings regarding the recognition failure of recallable words continued with Wiseman and Tulving (1976) in which the general trend of results was replicated using unrelated words as cues in the cued recall condition. Tulving and Thomson suggest that only encoding-specificity can explain the superiority of recall over recognition. They propose that when a memory is encoded it is encoded in such a way that it can only be retrieved through cues composed of items from that specific episode. Following that they suggest that items stored as cues at the time of learning are better equipped to retrieve a target than a copy of the target itself because the target had not be stored under the context of being used in a recognition task. Tulving and Thomson generalize the conclusions drawn from the recognition failure of recallable words series of papers in the following quote: "Specific encoding operations performed on what is perceived determine what is stored, and what is stored determines what retrieval cues are effective in providing access to what is stored" (Tulving & Thomson, 1973). Through this the authors suggest that what is most effective in accessing what is stored are the specific encoding operations originally performed. In the case of recognition failure of recallable words: a copy of the target fails to elicit a recognition response because the specific encoding operations did not prepare that memory trace to be accessed *via* recognition, but by recall using the appropriate cue instead. Subsequent work capitalized on this statement, such as transfer-appropriate processing (Morris, Bransford & Franks, 1977). Transfer-appropriate processing remains linked to encoding-specificity today (Braisby & Gellatly, 2005). The recognition failure of recallable words is counter-intuitive and remains an extreme example of encoding-specificity (Wiseman & Tulving, 1975). The existence of the effect lends support to another hypothesis as well: that approximating the learning conditions as much as possible leads to better retrieval performance.

1.2: *Encoding-retrieval match*

The encoding-retrieval match principle stipulates that retrieval performance is causally and monotonically related to the degree of match between the conditions at the time of encoding and conditions at the time of retrieval (e.g. Melton, 1963; Tulving, 1983; Tulving & Osler, 1968; Tulving & Thomson, 1973). The principle of encoding-retrieval match is often considered the primary determinant of memory retrieval performance (Toth & Hunt, 1999, but see Nairne, 2001, 2002 & Surprenant & Neath, 2009). Although the encoding-retrieval match principle is most often attributed to Endel Tulving (e.g. Tulving, 1983), it was first offered by Hollingworth (1928), then by Melton (1963) and credited by Tulving and Osler (1968). Following Tulving and Osler's (1968) assertion that encoding-specificity may support Melton's (1968) theory that retrieval depends on the completeness of the reinstatement of original stimuli, authors suggested encoding-specificity may be an underlying mechanism of what would later be called encoding-retrieval match (Tulving & Osler, 1968).

Yet, it is helpful to note that these two principles are different. The encoding-specificity principle states that a retrieval cue must be related to the original learning episode to be effective as a cue for that episode. If a cue possesses no feature present at the time of a given episode's original encoding, then the cue cannot contribute to retrieval from that episode. In this way – memories cannot be retrieved under conditions with zero encoding-retrieval match. However, the definition of encoding-specificity offered by Tulving and colleagues (i.e. Tulving & Pearlstone, 1966; Tulving & Osler, 1968; Thomson & Tulving, 1970; Flexser & Tulving, 1978) offers nothing related to the degree of encoding-retrieval match sufficient for retrieval, only that it must be present. Following a strict definition of encoding-specificity as offered by Tulving and colleagues, the relationship between encoding-specificity and retrieval is a binary function relating to whether or not retrieval may take place at all: (0) the present retrieval cue does not contain features that were present at the time of original encoding or (1) the present retrieval cue contains features present at the time of original encoding. The principle of encoding-retrieval match would be better described as a non-binary function related to retrieval performance or retrieval likelihood: "successful recall varies as a function of the number and appropriateness of retrieval cues" (Tulving, 1983, page 232). The concept that retrieval may be related to the *degree* of match between the time of encoding and the time of retrieval is superfluous to the encoding-specificity principle, and indeed stands on its own as a separate assertion.

Independent of encoding-specificity, the encoding-retrieval match principle is considered by many to be of central importance (e.g. Toth & Hunt, 1999). An intuitive interpretation of encoding-retrieval match suggests that any memory task must have some degree of match between conditions at the time of memory encoding and retrieval. Any change in conditions between encoding and retrieval represents a manipulation of encoding-retrieval match; with that in mind, the amount of available literature involving encoding-retrieval match is vast to the point of being practically impossible to cite. It should be noted that not all manipulations of encoding-retrieval match are meaningful to the point of being expected to elicit an effect (such as a change in the font size of words between learning and testing). However, some phenomena do stand out as being particularly important in support of encoding-retrieval match. For example, the encoding-retrieval match has been used to explain state or mood dependent memory, as a change in state or mood between encoding and retrieval constitutes a reduction in match (e.g. Eich, 1995). Tulving and colleagues point to a variety of context effects in support of both encoding-specificity and encoding-retrieval match (Wiseman & Tulving, 1975). The non-reinstatement of a learned context element at the time of testing constitutes a reduction in encoding-retrieval match. In that regard each beneficial effect of context reinstatement is at least partially in support of the encoding-retrieval match principle. The misinformation effect has been explained *via* encoding-retrieval match in that differences in information modality between encoding and retrieval have been put forward as a possible source of the effect, however there are numerous other explanations for the misinformation effect (Campbell, Edwards, Horswill, & Helman, 2007).

In order to clearly define the impact of state or mood on memory performance, Eich (1995) reviewed the literature on the subject and identified four essential factors within the phenomenon. Eich pointed to the distinction between internal and external events first under the hypothesis that changes in state or mood will have a greater effect on internal events (those conditions produced by the participant themselves through mental processes) than external events (manipulations imposed by an experimenter) as suggested by Eich and Metcalfe (1989). Eich and Metcalfe tested participants' memory for items that the participants either generated themselves or read from a list provided *via* the generate/read paradigm (Slamecka & Graf, 1978). In this way, Eich and Metcalfe tested material that had a source of an internal event (generate) or external event (read) and found that the effect of varying mood in this task had a significantly greater effect on material generated by an internal event than an external. Eich (1995) then described evidence suggesting that the nature of the retrieval task also plays a role in determining the size of an effect of mood dependence. Again citing Eich and Metcalfe (1989), Eich presented evidence that greater effects of mood dependence are present in free recall tasks than old/new recognition tasks. This data supports a general set of hypotheses which include the idea that mood dependence is most easily demonstrated in free recall tasks (e.g. Bower, 1981; Leight & Ellis, 1981; Ucros, 1989). Perhaps unsurprisingly, Eich mentioned that the strength of mood dependence depends on the intensity of the moods being manipulated. It had been demonstrated previously that unless the mood conditions differ greatly, and the conditions are each clearly represented by intense moods, then an effect of mood manipulation is unlikely to occur (Bower, 1992). The fourth and final point utilized by Eich (1995) regarded changes of affect involved in changes of mood. If participants are involved in an experimental condition in which they must learn items in one mood condition and then retrieve them in another, then the change in mood may also bring about a change in 'affective space' (Russel, Weiss, & Mendelsohn, 1989). In other words, some people may be able to move from a 'pleasant' mood condition to an 'unpleasant' mood condition without a change in arousal, but others may find the change to be generally distressing, resulting in arousal which constitutes its own set of variables. Presumably the participants greatly aroused by the change in mood should be excluded from the final data set in order to ensure a controlled manipulation of mood. This goes to demonstrate that the functional retrieval cue when manipulating encoding-retrieval match may contain any number of processes beyond the obvious. Although the existence of mood dependence effects generally supports the principle of encoding-retrieval match, these four points regarding state or mood dependent memory in Eich's (1995) article suggest that other factors are also at work. According to Eich it appears that there is a 'best' way of achieving effects of state or mood manipulation in an experiment: 1) test material that is produced by participants' 'internal events' or processes; 2) test the material using free recall or minimal cued recall; 3) ensure that the moods utilized in the manipulation are as intense as possible, and that they differ between contrasting conditions as much as possible. So, at least in the case of mood manipulations it could be said that encoding-retrieval match should not be the lone consideration in designing an experiment or making predictions of retrieval performance.

The misinformation effect pertains to the effect by which exposure to contradictory information following an event has a detrimental effect on memory for the original event (e.g. Loftus, 1975). Recent evidence has suggested that the encoding-retrieval match principle may be employed to explain this phenomenon. Campbell, Edwards, Horswill, & Helman (2007) investigated this possibility by showing participants a video of a mock crime. Participants were then provided either auditory or written narratives of the events in the mock crime that included reinstated, neutral, or misleading items of information. A forced-choice recognition test was then administered to participants in which they were asked to respond with what they remembered seeing in the video. In one of two varieties of recognition test participants were presented with original and misleading items or original and novel items (i.e. items that did not appear in either the source video or subsequent written or audio information). The critical prediction that encoding-retrieval match may explain the misinformation effect was expected by Campbell and colleagues to present an interaction. This interaction was predicted between information modality (text versus auditory) and information type (reinstated versus neutral versus misleading). Specifically it was predicted that in the condition in which participants were presented with written information following the source video, and were then tested with reinstated, neutral and misleading items in the recognition test – reinstated would be expected to exhibit higher performance than neutral, which would exhibit higher performance than misleading items. This was only predicted by Campbell and colleagues to be present for the written information condition, allowing for an interaction. The explanation offered by Campbell and colleagues for the difference between auditory and written modalities was that (as the recognition test was written) the auditory modality did not match the written modality of the test. A significant interaction between information modality and information type was found in Campbell, Edwards, Horswill, & Helman's (2007) experiments, suggesting that encoding-retrieval match may play a role in the misinformation effect. The modality manipulation of auditory and written information could be seen as a manipulation of context. Campbell and colleagues refer to it as a context manipulation at times in the article as well. This is representative of a large amount of encoding-retrieval match evidence which centres around manipulations of context (see Wiseman & Tulving, 1975). It should be noted, however, that in modality effect literature (i.e. matching or mismatching modality) the manipulation does not necessarily lead to these results (see Mulligan & Osborn, 2009 for a review).

Smith and Vela's (2001) meta-analysis reviewed investigations of context effects in memory within the specific area of incidental, environmental context. Incidental context typically refers to elements of the encoding or retrieval environment that are not central to the task at hand, or the primary focus of attention. Smith and Vela attempted to address the question of whether or not incidental context effects were reliable. The area of enquiry chosen by Smith and Vela appears to be due to what they perceived as a well-established amount of research in other areas of context related memory. Previous research regarding non-global context (context pertaining to a specific portion of the environment) (e.g. Murnane & Phelps, 1993, 1994, 1995), non-incidental contexts (context which is the focus of attention during the task) (Tulving & Thomson, 1973), and internal states (e.g. Eich, 1995) was regarded by Smith and Vela (2001) as being 'not in dispute.' Following their meta-analysis, Smith and Vela suggest that incidental, environmental context effects are reliable, barring any excluding effects such as overshadowing (the environmental context is suppressed for some reason at the time of encoding, likely due to demands elsewhere) or outshining (the environmental context is suppressed at the time of retrieval, likely due to the presence of an effective, non-contextual retrieval cue). Smith and Vela's meta-analysis concludes that effects of incidental context can be reliable, and as such lends support to encoding-retrieval match. However, it is clear through the provisos attached to this conclusion that other factors beyond encoding-retrieval match are at work. In order to demonstrate an effect of encoding-retrieval match for incidental context in the experiments reviewed by Smith and Vela the effects of overshadowing and outshining must be controlled for. In other words, encoding-retrieval match is reliable in these experiments so long as the task is not too demanding at the time of encoding and there are not more effective cues available at the time of retrieval.

There are those who suggest that the encoding-retrieval match may not be monotonically related to retrieval performance when counter-acting effects such as cue-overload are present (e.g. Capaldi & Neath, 1995; Craik & Jacoby, 1979; Nairne, 2002). Watkins and Watkins (1975), possibly the most frequently cited example of cue-overload, defined cue-overload as the effect by which retrieval performance decreases as the number of items in memory associated with the functional retrieval cue increases. An increase in encoding-retrieval match may also be accompanied by the addition of a cue-overload effect. The rationale for this is simple - an increase in encoding-retrieval match means an increase in similarity between the retrieval cue and a particular learned episode, but if that increase also means an increase in similarity to additional learned episodes then an increase in cue-overload is also evident. In this regard there are circumstances in which the well-documented effects of encoding-retrieval match and cue-overload are at odds with one another.

1.3: *Cue Overload*

Cue-overload was investigated by Watkins and Watkins' (1975) through the use of category names. Participants were presented with lists of categorized words as Brown-Peterson trials (Brown, 1958; Peterson & Peterson, 1959). In a typical Brown-Peterson trial, participants would listen to lists of 3 or 4 items and be asked to write those items in the original order following a distraction task. In Watkins and Watkins' (1975) study participants were presented with 20 Brown-Peterson trials with the first and last trials being used as 'buffer trials' that were not analysed. For the tested 18 trials the Brown-Peterson paradigm was altered slightly in that 15 of the 18 trials did not end in a memory test (i.e. only a distracter task). For the remaining 3 critical trials (and the 2 buffer trials), participants were tested following the distraction task (using category names as cues), as per a typical Brown-Peterson trial. Three lists from each of 6 categories were shown to participants. Participants were tested for all of the words of the experiment at the end. Watkins and Watkins' (1975) investigated the possibility of the build-up of proactive inhibition being explainable through the cue-overload effect. Proactive inhibition was defined as the effect by which performance generally decreases as the number of successive study/test cycles increases without a category change. In 1975, a typical investigation of the build-up of proactive inhibition would involve the study of a list followed by a recall test – within a few trials, it would be expected that performance would decrease with each list until the build-up of proactive inhibition was released (e.g. Keppel & Underwood, 1962). This could be achieved through a change in category type (Wickens, Dalezman & Eggemeier, 1976). Watkins and Watkins (1975) included this procedure in their experiment while also allowing 75% of the study lists to go initially untested. A typical effect of the build-up of proactive inhibition was demonstrated in Watkins and Watkins (1975) for tested lists. More specifically, their results showed that as the experimental session went on, participants' performance reduced. However, at the end of the experiment all lists were tested, including the initially untested ones. If retrieval performance for lists consistently declined as the experiment went on, then the reduction in performance could be attributable to the position of the list in the experiment. This would be indicative of proactive inhibition. However, although performance may decline across successive lists when each list is tested immediately after the distraction task, that decline in performance may not be due to the list's position in the experiment *per se*, but rather the number of lists drawn from a single category. It was shown that recall performance was independent of list position. In the final test, involving all lists, recall performance was evenly distributed across all lists of a category, pointing to a cue-overload explanation for the build-up of proactive inhibition effect. Experiment 2 of Watkins and Watkins (1975) varied the number of items per category and found a decline in effectiveness of category names as retrieval cues as the number of items per category increased. The importance of the cue-overload effect was highlighted by Watkins and Watkins (1975); their findings suggested that the number of items subsumed under a cue at the time of testing could be responsible for retrieval performance to a much greater degree than previously considered.

When considering effects of multiple memories being associated with a functional retrieval cue, cue-overload might be the principle most likely to come to mind. However, another classic effect (presented a year earlier) is similar. Anderson (1974) presented a series of propositions to participants of the form the [person] was in the [place], with the number of times certain people or places appeared in propositions varying. Participants would later be given a recognition task in the form of true/false questions concerning the studied propositions as well as lures, with response time measured. Anderson (1974) found that response time for correct recognitions increased as the number of occurrences of the person or place increased. This finding became known as the 'fan effect'.

Using sentences in the form of propositions as retrieval cues for facts concerning the people and places represented a novel means of cueing. The results of Anderson's (1974) experiment revealed a decline in retrieval performance as the number of items in memory (facts) associated with a given functional retrieval cue (people or places) increased. It is perhaps surprising that given the similarity between the fan effect and cue-overload that these two have been considered separate in the literature. Since the introduction of the fan effect into the literature its line of enquiry developed as a contrast to the multiple mental models explanation of memory (Radvansky, Spieler, & Zacks, 1993). This was done through the development of the ACT-R model (Anderson & Reder, 1999). It can be speculated that perhaps if the fan effect and cue-overload had been studied as one single principle the impact of that single principle may have been greater than the current impact of both cue-overload and fan effect research.

In a strict definition of cue-overload as described by Watkins and Watkins (1975), only the number of items in memory associated with the retrieval cue is important (i.e. the strength of association or the depth of initial processing may not be important). A large amount of work prior to 1975 was concerned with memory encoding (or learning) processes (e.g. Craik & Lockhart, 1972). Craik and Lockhart's highly influential article concerning the effects of deep versus shallow processing at the time of encoding is an iconic example of such work which relied on the encoding process as an explanation for later memory performance. After evidence began to amass that the retrieval process was dependent not only on the effectiveness of prior encoding processes but also on the properties of cues at the time of retrieval, Moscovitch and Craik (1976) continued to investigate such effects by comparing retrieval cues of various levels of hypothesized effectiveness. Across three experiments Moscovitch and Craik examined the effectiveness of depth of processing orthogonally across conditions of cue uniqueness. Experiment 1 of Moscovitch and Craik's study examined depth of processing in a similar way to Craik and Lockhart (1972), with depth of processing manipulated by use of one of three possible encoding questions. These encoding questions came in the form of 1) Does it rhyme with ___? 2) Is it in the category ___? 3) Does it fit in the sentence ___? Moreover, the list length and number of items per category were manipulated at learning. When tested participants were either tested with free recall, or in a cued recall task with category names as retrieval cues. The findings of experiment 1 indicated (perhaps unsurprisingly) that both the effects of depth of processing and cue availability (i.e. cued recall versus free recall) were significant, showing an advantage for cued recall and/or deep processing versus free recall and/or shallow processing. The cues used in the cued recall group of Moscovitch and Craik (1976) were the encoding questions used to process the targets originally in their respective depth condition, and those questions were unique to each target. Experiment 2 followed the same format, except that the manipulation of cue availability was removed (i.e. cued recall was used throughout) and the encoding questions were then shared amongst ten targets. For example, the encoding question 'does it rhyme with fog' would be used for ten target words. Moscovitch and Craik were then able to compare the results of the cued recall condition of Experiment 1 directly to experiment 2 as a manipulation of cue overload. The results suggested that independent of the number of items to be remembered in an experimental session, the number of items associated with a specific retrieval cue was the indicator of a cue overload effect. Further, that the effect of cue overload may have a link to the effectiveness of the cue in that the less effective cues (shallow processing condition) exhibited less of an effect of cue overload than the more effective cues (deep processing). Moscovitch and Craik (1976) concluded that uniqueness and depth of processing were similar due to their positive interaction. However, it may have merely been that the cue-overload effect is facilitated by the enhanced effectiveness of retrieval cues. Increasing the effectiveness of a retrieval cue associated with many potential candidates resulted in enhanced recall of many potential retrieval candidates, effectively reducing performance. An important finding of Moscovitch and Craik (1976), mentioned by the authors but perhaps with much less enthusiasm than it deserved, was that cues in the shared (increased cue overload) condition specified an encoding episode with much less precision than those in the unique cueing condition.

1.4: *Memory as Discrimination*

In the presence of cue-overload the ability to select the appropriate candidate for memory retrieval is the ability to discriminate between the appropriate candidates. In this way, for each act of remembering in the presence of any amount of cue-overload, memory is a discrimination problem. The greater the level of cue-overload present at the time of retrieval the greater the discrimination problem. However, it is not only the number of candidates associated with the cue at the time of retrieval (i.e. a strict interpretation of cue-overload) that matters. The likelihood of each of those potential candidates for retrieval is also important. The memory as discrimination view as offered by Nairne (2002) stipulates that memory retrieval performance depends on a diagnostic relationship between the cue and the target. In that regard it is the greatest amount of match to the target coupled with the least amount of match to competing memory traces which matters in optimizing retrieval likelihood (Poirier *et al*, in Press; Nairne, 2002). It is Nairne's (2002) memory as discrimination view that is under investigation within the present thesis. Under that view it is proposed that encoding-retrieval match is irrelevant to generating predictions of retrieval performance. This accords with Nairne's previous views in that within the feature model some manipulations of encoding-retrieval match, with cue-overload remaining constant, can result in a variety of outcomes (see Nairne, 2001; Surprenant & Neath, 2009). Under a memory as discrimination view the presence of cue-overload plays an important role in determining the likelihood of correct retrieval in that an increase in cue-overload leads to an increase in the number of potential candidates (Capaldi & Neath, 1995). What separates the memory as discrimination view from cue-overload, however, is that under a strict interpretation of cue-overload it is only the number of potential retrieval candidates which matters, whereas under a memory as discrimination view the likelihood of each of those candidates as a choice for retrieval is also important (Poirier *et al*, in Press; Nairne, 2002). Anything that would allow a retrieval candidate to stand out, or otherwise increase its likelihood of selection for retrieval should be considered when making predictions under a memory as discrimination view. These factors could be seen as distinctiveness effects (e.g. Hunt, 2003).

Previous work regarding cue-overload (e.g. Watkins & Watkins, 1975) and distinctiveness (e.g. von Restorff, 1933; Eysenck, 1979; Hunt, 2003; Nairne, 2006) has lead to the suggestion that discrimination problems may occur within the memory retrieval process. Hunt (2003) defines distinctiveness as '...the processing of difference within the context of similarity.' Distinctiveness effects allow one memory to stand out, relative to surrounding items, allowing less of a discrimination problem for that specific item. According to Hunt (2003) the idea that memories are distinctive because the items or some component of the items themselves are distinctive is insufficient, since drawing on the observable qualities of the items themselves does not describe the cognitive processes involved in the effect. Instead, Hunt (2003) suggests that the differences between to-be-remembered items are not sufficient to generate an effect of distinctiveness at the time of retrieval – it is the distinctive processing of those items relative to their context which matters. Similarity between items in the environment generates a context within which the differences between those items and the distinctive item may be perceived, but a relative difference at the time of learning may not be sufficient for distinctiveness effects to occur. Dunlosky, Hunt and Clark (2000) presented participants with isolation lists (i.e. one of the items in the list is separate from the others by an interval) in which the isolate appeared early in the list or half way through the list. Following each item participants were asked to judge how likely they would be to later remember the item. The results of Dunlosky, Hunt and Clark (2000) indicated that participants underestimated their ability to later remember isolates presented early in the list, but did not underestimate their ability to remember isolates presented half way through the list. This accords with earlier evidence (i.e. von Restorff, 1935). These results can be interpreted to suggest that whether or not one is aware of an item as being distinctive at the time of learning is not an adequate predictor of a distinctiveness effect at the time of retrieval. This could be seen as an indication that distinctiveness effects are effects of retrieval processes rather than learning processes.

The memory as discrimination view suggests that memory retrieval performance relates to the degree to which a retrieval cue is effective in specifying a candidate *to the exclusion of other candidates* (Nairne, 2002). Under a memory as discrimination view a manipulation of encoding-retrieval match between the cue and the target may be of benefit insofar as it specifies a single candidate, but it may have no effect if it also allows for an increase in similarity to other retrieval candidates, and may even be detrimental to the retrieval process if it coincides with a large enough increase in similarity to competing candidates (Nairne, 2002; Poirier et al, 2011). Hence, under a memory as discrimination view, the encoding-retrieval match is not only insufficient for explaining the retrieval process; it cannot be relied upon for generating predictions and should be considered irrelevant. The encoding-retrieval match has no place within the memory as discrimination hypothesis in that a diagnostic retrieval mechanism is the only one being considered (i.e. a mechanism in which a memory trace is specified to the exclusion of others regardless of the level of match).

What the encoding-retrieval match principle stipulates is specific; it describes the effect by which memory performance is expected to increase as the degree of match between those features present at the time of encoding and those present at the time of retrieval also increases (e.g. Tulving 1982). Under encoding-retrieval match a single memory is more likely to be retrieved as the retrieval cue more closely resembles the features present when the memory was originally formed. Intuitively however, it's simple to consider the possibility that when prompted by a retrieval cue (such as a question) it is possible to confuse two potential answers and respond incorrectly. That does not necessarily mean that the question more specifically targeted the incorrect answer. It may be that a chance configuration of conditions resulted in a bias that generated the incorrect response. Features matching between the time of encoding and the time of retrieval do not necessarily preclude the possibility of conditions at retrieval also matching conditions at some other time of encoding. Those 'other times of encoding' may allow for competing memory traces to be included as potential retrieval candidates, allowing them to be confused with the correct response.

When remembering occurs correctly it does so in spite of a possibility of confusion. With each memory retrieval scenario there is a possibility of confusing the 'correct' memory to be retrieved and some other memory. When a participant confuses a memory for the correct one and selects an inappropriate target for retrieval forgetting *via* discrimination failure has occurred. If forgetting is discrimination failure then remembering is discrimination success. Memory can be seen as a discrimination problem, one in which each retrieval cue searches through those candidates brought in to the search by the features of the cue (Nairne, 2002). If a cue consists of features indicative of only a small number of potential memories then it can be thought that perhaps that small number represents the number of competitors that would be relevant for a given memory search. Likewise, if a cue consists of features related to many memories then the number of competitors for retrieval would be relatively larger. If a memory is available for inclusion in a search then it stands that it may be retrieved and possibly used as a response. The more competing memories in a search, the greater the chance that the correct target will be confused with one of those competitors.

This is not to suggest that the only contributing factor to memory retrieval performance is the number of potential retrieval candidates (i.e. cue-overload). Assuming that the only factor of retrieval performance is the number of potential retrieval candidates is suggesting that all memory traces are equal, or at least that the relationship between a cue and potential retrieval candidate is the same for all potential retrieval candidates. If a trace is more similar to a cue than its competitors it may be the most likely candidate for retrieval, but there are many gradients of this. There could be a most likely candidate, a second most likely, a third, etc.

If the principle of encoding-retrieval match is to be accepted it should not be assumed that the only relationship to be considered at the time of retrieval is that between the encoding and retrieval environments for one single target. If one holds to the idea that memory relies not only on the retrieval of a single candidate, but also the rejection of other possible candidates then the following may be suggested: The principle of encoding-retrieval match describes not one but many relationships between the time of retrieval, and the many times of encoding previous episodes which now warrant consideration by virtue of the features present in the retrieval environment (e.g. Hunt, 2003; Nairne, 2002). In this way, the principle of encoding-retrieval match may be accurate while simultaneously self-defeating when there are multiple instances of match vying for retrieval selection.

To provide a simple numerical example, if encoding-retrieval match were described as a percentage of similarity between a trace and a cue, and if one trace-cue relationship had a similarity percentage of 50%, and the trace-cue relationship for any other competitor was 40% then one would expect that the former trace would be the more likely to be retrieved. Yet to continue the example, if the difference were much greater – if one trace-cue relationship had a similarity percentage of 90%, and the trace-cue relationship for any other competitor was 20% then again the former cue would be expected to be the most likely candidate for retrieval, but this time to a much greater degree than in the earlier comparison. In this regard it is not merely the number of competitors possible at the time of retrieval but the likelihood that those competitors could be retrieved that should be considered in determining the likelihood of retrieving the appropriate target under the memory as discrimination view. To take the example further: if an increase in encoding-retrieval match led to an increase in cue-overload (effectively adding new retrieval candidates), and those new candidates now have a 40% similarity to the cue, then it should be clear that a situation could arise such that the likelihood of retrieving the correct target could become less likely than it would have been without those new candidates having been introduced. This exemplifies a situation in which an increase in encoding-retrieval match results in a decrease in predicted retrieval performance under a memory as discrimination view.

This thesis will investigate the possible modes of interaction between (or contributions of) the well-established effects of cue-overload and encoding-retrieval match within the context of a memory as discrimination argument. The methods utilized involve the orthogonal manipulation of encoding-retrieval match and cue-overload across conditions in an effort to identify the contributions of each. Mathematical models of the processes involved in the memory as discrimination view are developed and examined against empirical data.

1.5: *Outline of the Thesis*

Chapter 2 provides empirical support for the memory as discrimination hypothesis through three paired-associate learning experiments while including interactive, environmental contexts. The memory as discrimination view is investigated in Chapter 2 across three experiments calling upon 'spot the difference' puzzles which are used as background images / context for paired-associate learning.

Chapter 3 extends the results of chapter 2 by building on Park, Arndt and Reder's (2006) 'font fan' effect. The experiments in chapter 3 offer the first data in which font is utilized to generate an effect of cue-overload, as well as the first data supporting the memory as discrimination view in terms of a proportion of correct responses. The experiments of Chapters 2 and 3 were included based on the idea that previous evidence regarding the memory as discrimination view has been in the form of response time measures. Chapters 2 and 3 present novel, empirical paradigms to test the memory as discrimination view in the proportion of correct responses.

Chapter 4 of this thesis investigates the roles of cue-overload and encoding-retrieval match in the retrieval process by providing regression models of both effects as they may pertain to the response times of participants. Three regression models are fit to data previously reported in Poirier *et al* (in Press); one model assumes that only cue-overload has an impact on retrieval performance, one represents a strict application of encoding-retrieval match as the only factor and one represents an equal contribution of both. The aim of the analysis offered in Chapter 4 is to determine the contributions and possible interactions of the effects of cue-overload and encoding-retrieval match in the response time data of experiments designed to test one of the more counterintuitive predictions of the memory as discrimination view: under certain circumstances increasing the encoding retrieval match can lead to a decrement in performance.

Chapter 5 continues the mathematical investigation of the effects of cue-overload and encoding-retrieval match through the use of mathematical models to predict the probability of correctly recalling a target given a retrieval cue. Chapter 5 offers an application of Shepard's (1987) similarity scaling algorithm in an effort to model the processes involved in a memory discrimination task. The parameters of Chapter 5's retrieval model are explored in reference to the predictions of the memory as discrimination view (Nairne, 2002). A qualitative fit to the trend of (proportion correct) data from Fowler, Poirier, Davelaar and Koutmeridou (submitted) is offered for two versions of the retrieval model in Chapter 5 for demonstrative purposes.

Chapter 2:

Diagnostic Retrieval And Interactive Contexts

2.1: Introduction

If one were to make the statement 'I can't find my coat,' a frequent reply might be 'Where did you see it last?' or 'Where did you last wear it?' It may be that returning to the location the coat was seen would help remember what became of the coat. It may also be that merely thinking about the last place it was worn would be helpful. Reinstatement of the location in which an episode took place is commonly thought to have beneficial effects on memory retrieval – but can it also be harmful? The present article will investigate the effects of context through a paradigm that allows for the possibility that context reinstatement may be associated with a variety of effects from the beneficial to the detrimental.

A context can be considered a portion of the retrieval environment which is not the focus of attention during a given task (e.g. Smith, 1979; Smith & Vela, 2001). This does not prohibit the possibility of context being a retrieval cue, or at least a portion of a retrieval cue, in a later retrieval attempt. In this regard the cue-overload effect (Watkins & Watkins, 1975) should apply to context as well. In the cue-overload effect retrieval performance declines as the number of items subsumed under a retrieval cue increases. For example, Fowler, Poirier, Koutmeridou, and Davelaar (submitted) demonstrated a cue-overload effect in a paired associates recall task where fonts were used as context; words printed in a unique font were better recalled than words that were printed in a font that was used for multiple items. Park, Arndt, and Reder (2006) had previously demonstrated a similar font effect with a recognition task.

Context reinstatement effects have frequently been reported in the literature (e.g. Smith & Vela, 2001). In a context reinstatement effect, performance improves when the context that was presented at study is also made available at the point of test, relative to a situation where the said context is not reinstated. The principle of encoding-retrieval match has often been used to explain these context reinstatement effects (Smith & Vela, 2001; Wiseman & Tulving, 1975). Under the encoding-retrieval match principle retrieval performance is considered to be causally related to the degree of match between the conditions at the time of encoding and the conditions at the time of retrieval (Nairne, 2002). Hence according to the encoding-retrieval match view, an attempt at retrieval without the original study context would be considered detrimental to retrieval performance as compared to that same attempt being made with the context reinstated (Tulving, 1983). Yet, a meta-analysis by Smith and Vela (2001) established that context effects are reliable only under certain circumstances, as many factors can contribute to an apparent null effect.

The memory as discrimination view offered by Nairne (2002) suggests that memory retrieval performance relates to the degree to which a retrieval cue specifies a target for retrieval. Under a memory as discrimination view, an increase in encoding-retrieval match can lead to a variety of outcomes, and may only lead to an increase in performance if the increase in match raises the diagnosticity of the cue. Hence, the memory as discrimination view further suggests that an increase in encoding-retrieval match can be accompanied by an increase in cue-overload. This can happen if the elements that are adding to the match are also recruiting competing candidates for retrieval. If this is the case, then it is possible that any beneficial effects of increased encoding-retrieval match could be reversed, effectively reducing memory retrieval performance. With that in mind it could be proposed that encoding-retrieval match does not matter at all, but rather that only a diagnostic retrieval mechanism is relevant in generating predictions.

Following Nairne's (2002) article championing a memory as discrimination hypothesis, a number of investigations have been centred on the relationship between the effects of encoding-retrieval match and cue-overload (Poirier *et al*, in Press; Fowler *et al,* submitted). Generally, until recently, encoding-retrieval match and cue-overload have been considered separate entities used to describe different situations, and hence studied in isolation. However, under a memory as discrimination view the effects of encoding-retrieval match and cue-overload are intertwined in a way that suggests a diagnostic mechanism for retrieval.

Within the history of context effects in memory, most of the attention has been centred on the beneficial effects of context (e.g. Smith & Vela, 2001). As mentioned above, a typical study of the effects of context involves a comparison between the reinstatement and non-reinstatement of study context. A typical hypothesis is that the reinstatement of study context will be beneficial to the retrieval process. Smith and Vela's (2001) meta-analysis aimed to address the question of whether or not context effects were reliable. Such a question was attended to perhaps because so many context experiments resulted in small or null effect that the reliability of context effects became suspect. Surprisingly, however, most of the early work on context focused on a paradigm in which context reinstatement was detrimental to retrieval performance (e.g. Bilodeau & Schlosberg, 1951). The 'interference reduction' paradigm of the 1950's was one in which participants were asked to learn a target list as well as an interference list – performance was reported to be higher when the interference list was learned in a different context to the target list (Bilodeau & Schlosberg, 1951; Eckert, Kanak & Stevens, 1984). Within the interference reduction paradigm the effect of context could be seen to be detrimental in one case – when a context element was shared between both lists. In the interference reduction paradigm, the context acted as a retrieval cue which retrieved the lists learned in that context. When only the target list was learned in a given context, then the reinstatement of that context at the time of testing acted as a retrieval cue which specified only the target list. When the context was shared between two lists at the time of learning, then the reinstatement of that context at the time of testing acted as a cue that retrieved both lists, allowing intrusions (i.e. interference) from the second list *via* cue-overload. Although context was reinstated in each case within the interference reduction paradigm one context reinstatement condition is preferable to the other when aiming for the highest retrieval performance. The context condition which specified the fewest retrieval candidates (the one list per context condition) resulted in the greater levels of performance.

The investigations of the present series study the effects of cue-overload and encoding-retrieval match in memory for words through orthogonal manipulation of both. The reinstatement of context at the time of retrieval is seen as an increase in encoding-retrieval match when compared to a condition where the context is not reinstated. Cue-overload is manipulated by varying the number of to-be-recalled items studied in a given context. When an increase in encoding-retrieval match also brings about an increase in cue-overload predictions become difficult; these two well-documented effects may be counteracting one another. Some may suggest that encoding-retrieval match is a more potent influence on retrieval performance than cue overload and thus suggest that such a situation would result in an increase in performance. Others might predict that retrieval performance is related to a lack of cue-overload in the retrieval environment and that in such an example retrieval performance would be expected to decline. Still another view would suggest that a null effect may arise. Simply put, not enough is known about the interaction between these two effects to warrant an accurate prediction (See Nairne, 2002 for a discussion of these three predictions). One of the aims of this paper is to reduce this gap in our knowledge.

The encoding-retrieval match principle has been considered one of the most important findings ever to be made in the study of memory (Toth & Hunt, 1999; but see Nairne, 2002, Surprenant & Neath, 2009). Still, one cannot discount the well documented effect of cue-overload. As the level of encoding-retrieval match in an environment increases the match increases between the retrieval environment and the correct target for retrieval. That does not preclude the possibility that match may also be increasing to competing (or incorrect) targets for retrieval. The effect of cue-overload pertains merely to the number of retrieval candidates under a cue. However, the memory as discrimination view posits an additional factor – not only the number of candidates but also the level of match between the cue and those candidates should be considered in determining retrieval probability. When cue-overload is present an increase in encoding-retrieval match may not be specifying a target. The increase in match may also pertain to competing memories.

When only one item in memory can be regarded as having a particular feature that item can be considered distinctive. As the amount of cue-overload associated with a retrieval cue increases it becomes more likely that distinctive features of memories become useful in identifying the most appropriate candidate for retrieval. When distinctive features are available the typical result is an increase in retrieval performance for those unique items (e.g. Hunt, 2003). Distinctiveness can only exist within the context of similarity according to Hunt. By this, Hunt suggests that it is not the features of the items *per se* which creates distinctiveness, but the features of the items as compared to the items around them. The relative distinctiveness of the cue to target relationship is linked to cue effectiveness (e.g. Hunt & Smith, 1996). In other words, if some features of a cue are unique to a target, then the cue is more likely to retrieve that target than a competitor. In Hunt and Smith's (1996) experiments participants were shown lists of words and asked to either write something about each word that did not apply to any other word in the list (item-specific) or to write something that applied to all words in the list (relational). The item-specific information would later be used as unique cues for targets in the list, whereas the relational processing would later be used as shared cues. At the time of testing participants were provided with their own unique or shared cues, or the unique or shared cues from another participant's list. The results of Hunt and Smith's (1996) experiments indicated that when words were encoded with regard to their item-specific features and were later cued by the participants' own unique cues retrieval performance was near perfect. If cued by another participant's unique cues, retrieval performance declined. However, if lists were encoded with regard to their relational features, then participants' own shared cues did not yield improved retrieval performance over the use of other participants' shared cues. In Hunt and Smith (1996) a reduction in encoding-retrieval match exists in each instance of a participant being cued by another participant's retrieval cues as opposed to their own. In the case of unique cues this resulted in a decline in performance, but in the instance of shared cues this did not. This is surprising in light of previous views that a reduction in encoding-retrieval match reliably results in a decline in performance (see Nairne, 2002). However, In Hunt & Smith's (1996) experiments, according to the authors' themselves, it is likely that some overlap existed between participants' shared cues. This means that although a reduction in encoding-retrieval match was present in the shared cue condition of Hunt & Smith's experiments, the participants' own shared cue was replaced by one which was similar to the one they had generated themselves. In that regard, the conditions of Hunt & Smith's experiments could be described as 1) a unique cue generated by the participant; 2) a unique cue generated by someone else; 3) a shared cue generated by the participant; 4) a shared cue generated by someone else. Conditions 2 and 4 represented a decrease in encoding-retrieval match, but in condition 2 the new unique cues provided to participants were highly dissimilar to the cues they generated themselves. The reduction of encoding-retrieval match for condition 4 was different in that the new shared cues provided to participants were relatively similar to the cues they had generated themselves. With shared cues being similar between participants it is perhaps not as surprising the reduction in encoding-retrieval match failed to generate a reduction in performance for that condition. In the present series, however, the materials used prohibit such an overlap between shared cues. In this way, the present series offers a manipulation of encoding-retrieval match for shared cues which does not replace those shared cues with similar shared cues. Rather, the manipulation of encoding-retrieval match is equal across unique and shared cue conditions in the present series.

Experiment 1 of the present series begins the investigation into the effects of cue-overload and encoding-retrieval match by assessing the validity of spot the difference (STD) context images as a means of generating a cue-overload effect; the images are considered to be an incidental context. Participants were required to study pairs of words (paired associates) with these images as a backdrop; they were told that, at test, one word was going to be used a cue for the recall of the other. The word pairs were studied either on a unique STD image, or an STD image that was shared by five paired associates. A cue-overload effect of context would mean a lower proportion of correct responses for the pairs sharing an STD image than for the unique STD image condition.

2.2: EXPERIMENT 1

Participants

City University London students (n = 20) volunteered to take part in this experiment. Undergraduates received course credit for participation; graduates received £7. Of the 20 participants 14 were native speakers of English while the remaining 6 spoke fluent English as a second language.

Materials & Design

Target words were assembled from the Toronto Noun Pool (Friendly, Franklin, Hoffman & Rubin, 1982) with a mean Kucera-Francis written frequency of 62.38 and concreteness rating of 5.32. The task involved solving 'spot the difference' (STD) puzzles followed by cued recall of paired associates. Each time a participant spotted a difference a clicked on that difference on the screen a paired associate would appear. Cue words were deliberately chosen based on the accompanying spot-the-difference context image. All words were composed of two syllables. Words were randomly assigned to pairs and then deliberately re-arranged to avoid strong pre-experimental associations between the words where necessary. Pairs were arranged to avoid rhyming or alliteration. Words were assigned to lists in such a way as to avoid multiple words in a list being categorically or phonetically similar. There were 10 pairs per list and 8 lists in the experiment. There were six images per list, one image for the five pairs associated with the shared context condition, and five images each uniquely associated with one word pair. The 48 STD puzzles were selected from Arcturus Publishing's (2007) Brain Benders™ book (with permission). The images were in black ink on a white background with no shading. Each image involved a scene with characters interacting with their environment.

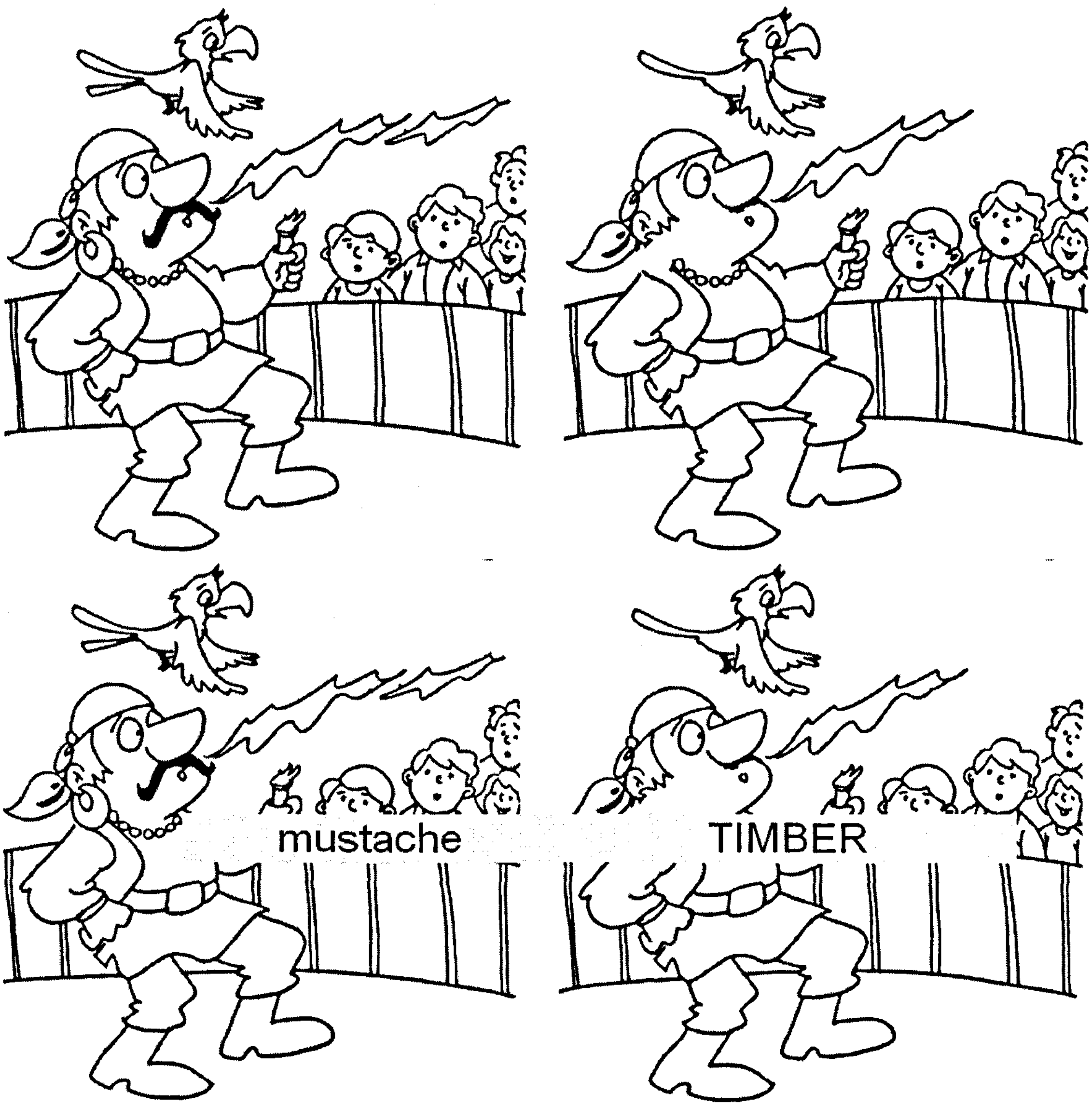


Fig. 1. an example of a shared spot-the-difference image. The top pair of images shows what a participant would see before clicking on a difference. The bottom pair shows the pair of words that would appear for a participant after clicking on the moustache of the performer in the image on the left.

Forty of the images were assigned to a condition in which only one difference could be spotted; in other words, those images would be used as a backdrop for the presentation of one word pair only. The cue word was linked to the difference. For example, in Figure 1 above, a difference to be identified is the moustache of the performer. As the cue words for each pair pertained to differences to be spotted in images and no word could appear more than once in the Experiment, this resulted in only a partial counterbalancing of images to cue conditions. Although two sets of shared and unique images were used, there was no random assignment of images to conditions. Once a participant had clicked on the location of this difference, the word pair appeared. This represented the 'unique' context condition. The remaining 8 images were assigned to a condition in which five differences could be spotted. For those images, the five differences were each associated with a pair of words, with a link between the cue words and the differences, as before. This represented the 'shared' context condition. Two variations of these assignments were arranged (i.e. images assigned to the shared condition would be made into unique images, and some of the unique images were arranged into shared images). Participants were randomly assigned into one of the two image arrangement groups. This was done only as a control for the possibility of effects of the images themselves. Memory for the target words was tested after each list. A Microsoft Visual Basic™ purpose-built application was used to randomize and order the presentation of trials and collect user responses. This software was used to randomize the order of list presentation, trials within lists, and again within test lists for each participant. In this way, the presentation order of shared versus unique items was random. Although cue words were associated with differences found in each image, the target word to be recalled was a random assignment, and randomized in the same manner as the presentation order.

Procedure

Participants were tested in one session lasting approximately 45 minutes. Instructions were presented on a computer screen before the first trial. Included in the instructions was a description of the STD task in which participants were notified that images contained either one or five differences. Participants were asked to click on the location of a spotted difference, on the left image. Participants were then instructed that following successful identification of a difference two words would be presented, one lower-case and one capitalized. They were instructed that there would be a memory test after the presentation of 10 pairs; that the lower-case word would be provided and that they would need to recall the correct accompanying capitalized word. Once participants began the task they were presented with a pair of STD images. Once a difference was spotted the corresponding word pair appeared on the screen for 4 seconds as in Figure 1. In the event of a shared image being presented – all five differences were simultaneously visible, but only one of the five differences would produce a word pair when clicked. Participants were instructed that if they clicked on a difference that did not produce a word pair, they should continue searching the image and clicking on differences until the word pair appeared. It was made clear to them that an identified difference could produce a word pair later on in the trial. Once a word pair appeared another random selected STD image from the list would appear. This continued until all of the word pairs from the list had been presented. The cue word always pertained to the difference spotted, whereas the target word was a purely random selection from the list of possible target words. All word pairs were presented in the foreground of the STD images after clicking. Word pairs remained on the screen for 4 seconds, followed by a .5 second pause before the next trial. After 10 such trials participants were presented with the test phase. Within a test phase participants were presented with each cue word in the foreground of its corresponding STD image. A white, blank input field was presented in place of the target word, and participants had been instructed to type the appropriate word using their keyboard.

2.2.1: *Results & Discussion*

Experiment 1 was designed to test the possibility of a cue-overload effect for STD images that were used for 5 word pairs when compared to STD images used only for one word pair. An effect of cue overload was predicted in that pairs presented with shared STD images were expected to be less well remembered than those presented with unique STD images. Figure 2 shows the proportion of correct responses per condition, and suggests a cue overload effect, as predicted.

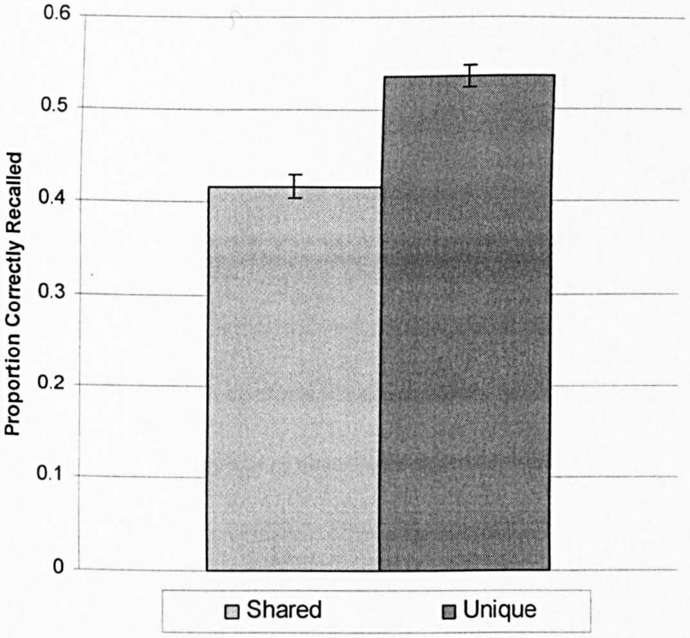


Fig. 2. Mean proportion correct per STD context condition obtained in Experiment 1 (error bars represent SE of the mean). Shared refers to the condition in which five word pairs shared the same STD context image. Unique refers to the condition in which each word pair was presented with its own unique STD context image.

A paired samples T-test found the shared and unique STD context conditions to differ significantly (*t* = -4.70, p<.001 [two-tailed], Cohen's *d* = .46) indicating an effect of cue-overload for context. Those word pairs presented on a shared STD image were less well remembered than those presented on a unique STD image. The mean proportion correct for the shared condition was .45 (σ = .13) versus .56 (σ = .12) for the unique condition.

If the effect of cue-overload is obtained by reinstating a shared STD image at the time of testing, then omitting that image at the time of testing should be of some relative benefit. Experiment 2 will examine the prediction of the memory as discrimination view through replicating the conditions of Experiment 1 and adding a manipulation of encoding-retrieval match. The manipulation of encoding-retrieval match comes from the non-reinstatement of the STD image at the time of testing in Experiment 2. In this regard, the memory as discrimination prediction for omitting STD images at the time of testing (the 'absent' condition) is that of an interaction between the unique and shared STD image conditions. This interaction is expected to be evident by way of a detrimental effect of non-reinstatement of the STD image in the unique condition, but no such detrimental effect in the shared STD image condition. In Experiment 2 participants are presented with word pairs and STD images in an identical way to Experiment 1. However, at the time of testing the previously presented STD images are either reinstated or absent. The memory as discrimination predictions are that the basic effect of cue-overload as demonstrated in Experiment 1 will be replicated – that items presented with a unique STD image will be better remembered than those presented with a shared STD image (a cue overload effect). Further, the view predicts that the omission of STD images in the unique condition will result in a reduction of the proportion of correct responses versus the reinstatement of those images (as encoding retrieval match is reduced and cue overload remains unchanged). Finally, the view predicts that the omission of the shared STD image will either result in an improvement or no change in performance relative to the condition where the shared STD image is reinstated. This is because reinstating the shared context images both increases encoding retrieval match and cue overload simultaneously.

2.3: EXPERIMENT 2

Participants

City University London students (n = 27) volunteered to participate in this study. Participants were each rewarded with a £7 Amazon™ Gift Voucher. Of these participants 19 were native English speakers whereas the remaining 8 spoke fluent English as a second language.

Materials, Design & Procedure

All of the materials used in Experiment 2 were identical to those in Experiment 1. The primary manipulation of Experiment 2 was in the test phase. In the test phase of Experiment 2 the STD context image was either present or absent. As there were five unique and five shared context pairs per list the number of reinstated context images per condition alternated such that there were five reinstated context images per list (e.g. with three in the unique condition and two in the shared condition and *vice versa*) that evened out by the end of the Experimental session.

2.3.1: *Results & Discussion*

Experiment 2 was designed to test the prediction that while the omission of spot the difference (STD) context images at the time of testing for items originally presented with a unique STD image should result in a reduction in the proportion of correct responses, a reduction should not be evident for those items originally presented with a shared STD image. Figure 3 appears to support that prediction, with a reduction in proportion of correct responses in the unique condition when the STD image is absent at the time of testing, whereas there is no such reduction apparent for responses in the shared condition.

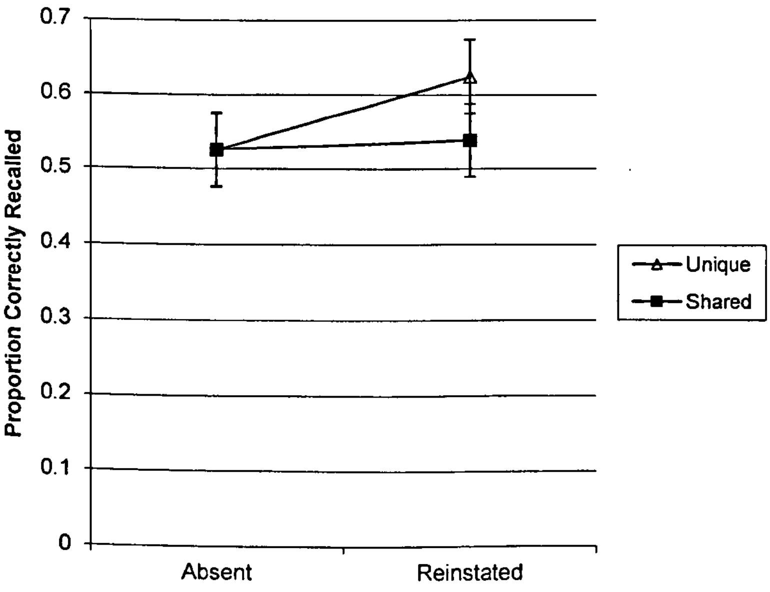


Fig. 3. Proportion of correct responses for those items originally presented on a unique or shared STD image, with that image being either reinstated or absent at

the time of testing. Shared refers to the condition in which five word pairs shared the same STD context image. Unique refers to the condition in which each word pair was presented with its own unique STD context image.

The predictions of the memory as discrimination view were supported in that a within-subjects analysis of variance (ANOVA) revealed a main effect of learning condition (unique versus shared), ($F(1, 26) = 6.59$, MSE = .049, $p < .05$), replicating the findings of Experiment 1 in that unique STD image items were better remembered than shared image STD items when the STD images were reinstated at test. A main effect of testing condition (reinstated versus absent) was found ($F(1, 26) = 13.60$, MSE = .083, $p < .01$) in that the reinstatement of STD images shown to be beneficial. A learning by testing condition interaction ($F(1, 26) = 9.25$, MSE = .050, $p < .01$) was also found, demonstrating that although reinstatement of the STD image was beneficial in the unique items condition, it was not so in the shared image condition. A planned means comparison revealed a significant difference between reinstated and absent images in the unique STD image condition ($t = -4.65$, $p<.001$ [two-tailed], Cohen's $d = .38$) indicating that the reduction of encoding-retrieval match at the time of testing for pairs in the unique condition did have an effect. However, for pairs presented in the shared STD image condition no significant difference was revealed. The mean proportion correct for the shared, reinstated condition was .53 ($\sigma = .19$) versus .62 ($\sigma = .20$) for the unique, reinstated condition. The mean proportion correct for the shared, absent condition was .53 (σ = .21) and .53 (σ = .19) for the unique, absent condition.

Again, as the STD task was identical to that in Experiment 1, participants are made to attend to the STD images in order to receive the cue word. As the basic effect of cue-overload of STD image was replicated in Experiment 2 it is likely that these images are being encoded along with the word pairs. The effect of the omission of STD images in the unique image condition demonstrates the degree to which one might expect the reduction of encoding-retrieval match to have an effect in the present series. Yet when the same reduction of encoding-retrieval match is introduced for the shared images condition there is no such effect. The interaction between the unique and shared STD image conditions is in line with the memory as discrimination prediction that encoding-retrieval match and cue-overload interact in such a way that an increase in encoding-retrieval match may result in a reduction, no change, or an increase in retrieval performance dependent upon the degree to which the retrieval cues present can specify a target for retrieval.

Experiment 3 investigates the possibility that an effect of cue-overload tied to context may be effectively transferred to items not originally learned in that context. Following an identical learning paradigm as Experiments 1 and 2, the test phase in Experiment 3 presents participants with either the original STD image, or an STD image from the contrasting condition (i.e. the images are swapped). The memory as discrimination view would predict that pairs originally learned on a unique STD image but presented during the test phase on a shared STD image will inherit the cue-overload associated with that shared image, effectively reducing retrieval performance.

2.4: EXPERIMENT 3

Participants

City University London students (n = 27) volunteered to participate in this study. Participants were rewarded with a £7 Amazon™ Gift Voucher. Of these participants 20 were native English speakers whereas the remaining 7 spoke fluent English as a second language.

Materials, Design & Procedure

All of the materials used in Experiment 3 were identical to those in Experiments 1 and 2. The primary manipulation of Experiment 3 was in the test phase. In the test phase of Experiment 3 the STD context image was either the original one presented with the cue word at the time of learning, or was swapped with an item of the contrasting condition. As there were 5 unique and 5 shared context condition trials per list the number of reinstated context images per condition alternated such that the number of reinstated versus swapped trials averaged to five by the end of the Experimental session (i.e. if one list had 6 swapped trials at test, the next list would have 4).

2.4.1: *Results & Discussion*

Experiment 3 aimed to investigate the possibility that when a cue-overload effect is present for a set of context cues in one instance, that cue-overload effect may be transferred to another set of cues. In contrast to Experiment 2, the trials in the test phase of Experiment 3 that receive a swapped STD image not only receive a decline in the level of encoding-retrieval match, but also inherited cues which match other retrieval candidates. The unique/reinstated condition is again predicted to demonstrate the highest proportion of correct responses. Following that, the shared/reinstated condition (possessing no reduction in encoding-retrieval match, and having an association to five intra-list retrieval candidates) would be expected to exhibit the second highest proportion of correct responses. The unique/swapped and shared/swapped conditions each involve a similar decline in encoding-retrieval match and each have an association to six intra-list retrieval candidates. Hence, these conditions would be expected to produce the lowest proportion of correct responses and be comparable to one another. Figure 4 appears to exhibit these trends.

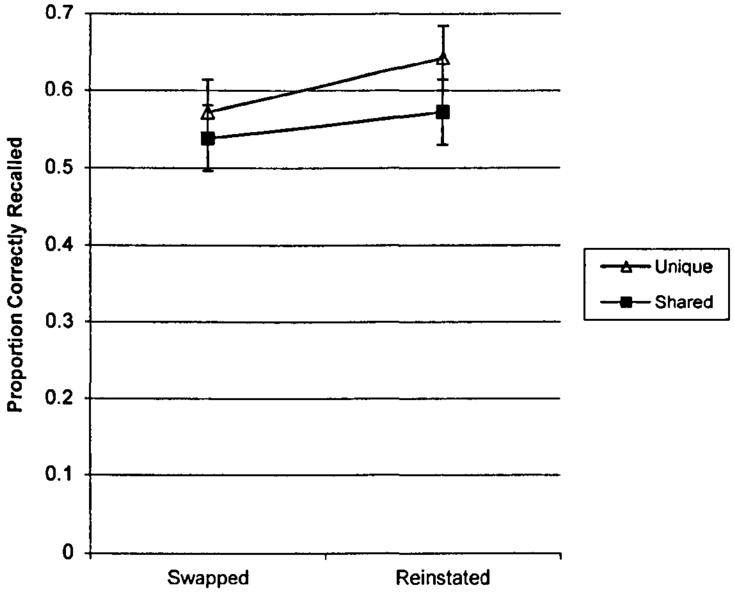


Fig. 4. shows the proportion of correct responses for those items originally presented on a unique or shared STD image, with that image being either reinstated or swapped at the time of testing. Shared refers to the condition in which five word pairs shared the same STD context image. Unique refers to the condition in which each word pair was presented with its own unique STD context image.

The series of predictions offered by the memory as discrimination view (i.e. that unique/reinstated > shared/reinstated > unique/swapped = shared/swapped) appear to correspond reasonably well to the means observed. The mean proportion correct for the shared, reinstated condition was .57 (σ = .29) versus .64 (σ = .2) for the unique, reinstated condition (*t* = 2.61, p=.015 [two-tailed], Cohen's *d* = .34). The mean proportion correct for the shared, swapped condition was .54 ($\sigma = .21$) and .57 ($\sigma = .25$) for the unique, swapped condition ($t = 1.42$, p=.167 [two-tailed], Cohen's $d = .11$).

Qualitatively speaking the only data point that does not conform to the memory as discrimination prediction is that of unique/swapped. The unique/swapped condition is expected to be approximately equal to the shared/swapped condition. Instead, it is approximately equal to the shared/reinstated condition. The shared/swapped condition appears to exhibit a lower proportion of correct responses than the shared/reinstated condition, which was not expected.

A within-subjects analysis of variance (ANOVA) revealed a main effect of learning condition (unique > shared), ($F(1, 26) = 7.29$, MSE = .072, $p \approx .01$), replicating the findings of Experiment 1. A main effect of testing condition (reinstated > swapped) was found ($F(1, 26) = 7.44$, MSE = .072, $p \approx .01$). In contrast to Experiment 2, the learning by testing phase interaction was not present.

2.5: *General Discussion*

Through the use of shared spot the difference (STD) images as context the Experiments presented in this paper demonstrated manipulations of both encoding-retrieval match and cue-overload. In Experiment 1 a cue-overload effect of STD context images was demonstrated. Word pairs presented with a unique STD image at learning and testing were compared with word pairs presented with a shared STD image at learning and testing in Experiment 1. The result demonstrated a typical effect of cue-overload, as word pairs presented with a unique STD context image were better remembered than those presented with a shared STD context image. With an effect of cue-overload of STD context image having been established by Experiment 1, Experiments 2 and 3 manipulate encoding-retrieval match in two ways. Experiment 2 replicated the effect of cue-overload of Experiment 1 while introducing a manipulation of encoding-retrieval match at the time of testing. In the test phase of Experiment 2, the STD context image that had previously been presented at the time of learning was either reinstated or absent. The results demonstrated an interaction between the learning condition (unique or shared) and the testing condition (reinstated versus absent). Word pairs originally learned with a unique STD context image and then tested with that context image reinstated were better remembered than word pairs originally learned with a unique context images and then tested in the absence of that context image. This demonstrated a typical effect of encoding-retrieval match. This effect was not present for the shared STD context image condition. Word pairs originally presented with a shared context image and then presented at test with that context image reinstated were not better remembered than pairs originally presented with a shared context image and then tested in the absence of that image. It should be noted that this does not preclude the possibility of encoding-retrieval match having an effect on the shared context image. It can be assumed that the reduction of encoding-retrieval match could have the same effect on both unique and shared context image pairs in Experiment 2. The interaction could then be explained by the beneficial effect of a reduction in cue-overload for items in the non-reinstated, shared context image condition.

Experiment 3 again replicated the cue-overload effect of STD context image demonstrated in Experiments 1 and 2. The manipulation of encoding-retrieval match utilized in Experiment 3 differed from that in Experiment 2. Instead of simply removing the STD context images as a manipulation of encoding-retrieval match, Experiment 3 swaps the context images with the contrasting condition for half of the word pairs at test. This resulted in a pattern of results apparently similar to those from Experiment 2. The difference is the lack of interaction in the Experiment 3 results. One possible explanation for this lack of interaction could be that those pairs originally presented with a shared STD context image and then tested with a unique image did not have the same reduction of cue-overload demonstrated in Experiment 2. When a shared context image was swapped with a unique one, it did result in a reduction of cue-overload, but it also inherited an association to the word pair with which the unique image had originally been presented. In this way, the reduction of cue-overload for the shared/absent condition of Experiment 2 was greater than the reduction of cue-overload for the shared/swapped condition of Experiment 3.

The results reported in Experiments 2 and 3 support previous work regarding the memory as discrimination view (Nairne, 2002; Poirier, Nairne, Morin, Zimmerman, Koutmeridou & Fowler, submitted) in that only the cueing condition in which a single retrieval candidate was specified had a reliable advantage (i.e. the unique/reinstated condition). The effect of encoding-retrieval match was shown to be present in that the unique/reinstated condition was reliably better remembered than the unique/absent (Experiment 2) or unique/swapped (Experiment 3) conditions. Cue-overload effects of context are apparently scarce in the extant literature, and the reliable effect of cue-overload of context across all three Experiments of the present series is a contribution in that regard. The data does support Hunt and Smith's (1999) relational versus item-specific processing work in that both can be seen as manipulations of context. In Hunt and Smith, the participants' focus on the features of the items which could be seen as unique (item specific) or shared (relational) could be regarded as a conceptual context. The unique versus shared visual, interactive contexts of the present series may be a different form of context, but the images themselves link the word pairs together into a conceptual framework. When Hunt and Smith manipulated encoding-retrieval match in their Experiment by replacing the participants' generated cues with someone else's cues their pattern of results was similar to those of Experiments 2 and 3 of the present series. The confound noted by Hunt and Smith in their study, that the cues used by different participants for the shared (relational) condition were similar to one another does not apply to the present series. In this way the present series lends some support to Hunt and Smith (1999) while controlling for that confound.

In light of the findings of the present study as well as those from previous memory as discrimination investigations it is becoming increasingly evident that the principle of encoding retrieval match needs to be qualified (e.g. Nairne, 2002; Poirier *et al*, in press). With the view that the degree of match between conditions at encoding and conditions at retrieval is monotonically related to retrieval performance (Tulving, 1983 but see Nairne, 2002) there comes an assumption – that all matching features are beneficial. It is more likely, however, that not all features of the learning environment will affect retrieval the same way when reinstated. Some features, such as those containing an effect of cue-overload as in the present study, may be harmful. When relying on the encoding-retrieval match principle it may be valuable to consider these possibilities.

Chapter 3:

Discrimination Problems And Incidental Context

3.1: Introduction

The encoding-retrieval match principle has become one of the cornerstones of the cognitive psychology of memory (see Nairne, 2002). According to the encoding-retrieval match view, memory retrieval performance is related to the degree of compatibility between the cues at the time of encoding and the cues at the time of retrieval (Tulving, 1979, 1983). Encoding-retrieval match has often been called upon to explain context effects, particularly when the context is incidental (e.g. Wiseman & Tulving, 1975; Smith & Vela, 2001); an incidental context is any (processed) portion of the environment not directly relevant to the task at hand.

However, the usefulness of the encoding-retrieval match idea has recently been challenged by what is referred to as memory as discrimination (Nairne, 2002; Hunt, 2003; Poirier *et al*, in Press). The backbone of the memory as discrimination view is the idea that memory retrieval depends on a diagnostic relationship between the retrieval cue and the to-be-retrieved target. Within a diagnostic cue-to-target relationship, the cue specifies a target for retrieval to the exclusion of other, competing retrieval candidates (Nairne, 2002; Hunt, 2003). The ability of a retrieval cue to exclude other potential targets for retrieval is related to its level of cue-overload. Cue-overload is the effect by which retrieval performance is expected to decrease as the number of items subsumed under a retrieval cue increases (Watkins & Watkins, 1975). Under a memory as discrimination view, the diagnostic value of a cue decreases with the number of competing targets (i.e. a low amount of cue-overload). The objective of this series is to investigate the interaction of encoding-retrieval match and cue-overload on memory retrieval performance for words, and to establish the role of incidental context in producing effects of encoding-retrieval match and cue-overload.

Underlying both cue-overload and encoding-retrieval match is the concept of encoding specificity. The encoding specificity principle states that a retrieval cue will only be effective if it was learned at the time of encoding the target item (e.g. Tulving, 1979). The encoding-retrieval match idea emerged from the encoding specificity literature; the idea was that the closer one approximates the original learning environment the more likely one is to match the specific trace created at the time of learning. However, as has been demonstrated and replicated thoroughly since Watkins & Watkins (1975), cue-overload may occur if multiple memory traces contain some of the features of the retrieval cue, resulting in a decline in performance. When situations arise in which an increase in encoding-retrieval match allows for a closer approximation of the original learning episode, but also allows for the inclusion of additional retrieval candidates via the cue-overload effect, the predicted outcome becomes unclear.

To adopt a simple example, if cue *afg* has correct response *X* and cue *ade* has correct response *Y*, how would the outcome of a variety of cueing conditions be predicted by encoding-retrieval match, cue-overload, and memory as discrimination views? Cues *afg* and *ade* have a feature in common (*a*). A pure encoding retrieval match view would predict that the more features provided at test that match the target, the better. Hence under an encoding-retrieval match view, the cue *afg* would be best for attempting to successfully retrieve target *X*, and barring any consideration of cue-overload, cues *af, ag, or fg* would be less effective as retrieval cues. Any further reduction in encoding retrieval match (e.g. *a, f,* or *g* alone) would be predicted to be even less effective. Under a pure cue-overload view, the cues *f, g,* or *fg* would be the best cues, and given no consideration of encoding-retrieval match would be considered equally well suited. This would be because *a* contains an element of cue-overload, making its exclusion the best idea under a pure cue-overload assumption.

Under a memory as discrimination view, the diagnostic value of the cue is what matters most. The most diagnostically valuable cueing condition for response *X* would be *fg*, as it contains the greatest amount of encoding-retrieval match while excluding the maximum amount of cue-overload. Then, let us assume cue-overload and encoding-retrieval match are equally potent – as a simple case for this example's sake. Following that, cue *afg* would be the second best option, as the benefit of encoding-retrieval match (afg > fg) would counter the decrement due to cue-overload (a cues both X and Y). Cues *f* and *g* alone could be considered equally valuable to *af* or *ag* due to the fact the increase in encoding-retrieval match would be cancelled by the equally powerful increase in cue-overload. Cue *a* alone would be the least diagnostically valuable due to the obvious fact that it is not possible to specify either *X* or *Y* given *a* alone.

If the conditions at the time of learning are increasingly approximated at the point of retrieval, it may be that the correct memory trace will be a candidate for recall. However, any other traces that share these conditions (included by way of cue-overload) may also be likely retrieval candidates. In this way, both encoding-retrieval match and cue-overload rely on encoding specificity being accurate, but the precise effect of encoding-retrieval match and cue overload would depend on the circumstances. In some cases, such as when an increase in cue-overload means the addition of retrieval candidates highly confusable with the appropriate target, cue overload may counter any increase in encoding-retrieval match. In this way it could be suggested that encoding-retrieval match should not be considered in generating predictions. Rather, a diagnostic mechanism in which performance favours a cueing environment in which a retrieval candidate is specified regardless of match could be seen as preferable under a memory as discrimination view.

Recently, contextual cues were used to produce a cue overload effect within a recognition paradigm. Park, Arndt and Reder (2006) were able to demonstrate that recognising words that were all presented in the same font was more difficult than recognising words that were presented in unique, non-repeated fonts. This was called the 'font fan' effect. The methodology of Park et al. (2006) involved presenting participants with words in unusual fonts and colours. A varying number of words were presented in the said fonts and colours. A 'high fan,' (i.e. presented with many words) colour or font was shown with 24 words, versus only 3 words with a 'low fan' (i.e. presented with few words) colour or font. At test, participants were shown the words with one of the two (font or colour) features reduced to 'neutral' (i.e. colour was replaced with black, or font was replaced with Times New Roman). Participants were then tested using Tulving's (1985) remember/know recognition test. The results showed an increase in false alarms for the high versus low fan font, along with a decrease in 'remember' and corresponding increase in 'know' responses for the high fan versus low fan font. This suggested that font may be a suitable mode of incidental context manipulation for the present series. Extending the font fan effect to a paired-associate cued recall paradigm, the present series aims to investigate the role of cue-overload and encoding-retrieval match through orthogonal variations of both. In particular the present series tests the most controversial prediction of the memory as discrimination view: that a decrease in encoding-retrieval match could result in an increase in retrieval performance.

In all the Experiments reported here, participants were asked to learn paired associates and retrieve one member of the pair using its associate as a retrieval cue. Words were presented in unusual fonts taken from an online font database (fonts.com, 2008). The fonts were elaborate, decorative, and unique. Experimental manipulations of these fonts allowed for the investigation of their value as incidental context cues, and to determine whether or not systematic manipulations of those cues supported an encoding-retrieval match, or a memory as discrimination point of view. Experiment 1 was designed to test if fonts could reliably produce a cue-overload effect in a cued-recall paradigm: As such, typical cue-overload evidence was predicted as the result of Experiment 1.

3.2 EXPERIMENT 1

Participants

City University London students (n = 20) volunteered to take part in this Experiment. Undergraduates received course credit for participation; graduates received £5. Of these participants 15were native English speakers whereas the remaining 5 spoke fluent English as a second language.

Materials & Design

The task was a paired-associate cued recall task that first involved learning to associate two unrelated words. Twelve lists each containing twelve paired associates were presented to participants. Six of the 12 pairs from each list were presented in the same font and the remaining six were each presented in a unique font. With six pairs per list sharing the same font it was predicted that the font would create a cue-overload effect, reducing performance for the pairs presented in the shared font relative to those presented in a unique font. Word pairs within each list were randomly assigned to either unique or shared font conditions. Within a pair, both words were always presented in the same font, regardless of unique or shared font condition. At test, participants were presented with only the first word of the pair and asked to recall its associate. Word pairs were assembled from the Toronto Noun Pool (Friendly, Franklin, Hoffman & Rubin, 1982) with a mean Kucera-Francis written frequency of 62.38 and concreteness rating of 5.32. All words were composed of two syllables. Pairs were deliberately arranged to avoid strong pre-Experimental associations between the words. No two words in a pair shared the same first letter or rhymed with one another. Words were assigned to lists in such a way as to avoid multiple words in a list being categorically or phonetically similar. The fonts were elaborate or otherwise infrequently used fonts derived from an internet font database (fonts.com, 2008). A pre-Experimental questionnaire was completed by six graduate students to scale 164 fonts in terms of legibility on a five-point rating scale. Fonts were assigned to conditions in such a way that the mean legibility of fonts did not differ between the unique and shared font conditions. Unique fonts received a legibility rating mean of 3.49 (s.d. 0.96, range 3.60). Shared fonts received a legibility rating mean of 3.53 (s.d. 0.94, range 2.80). A purpose-built Authorware™ software program was used to order the presentation of pairs within each list, order the presentation of lists within the Experimental session, and collect user responses. See Figure 1 for an example of word pairs assigned to shared and unique font conditions. Words were not randomly assigned to fonts in Experiment 1.

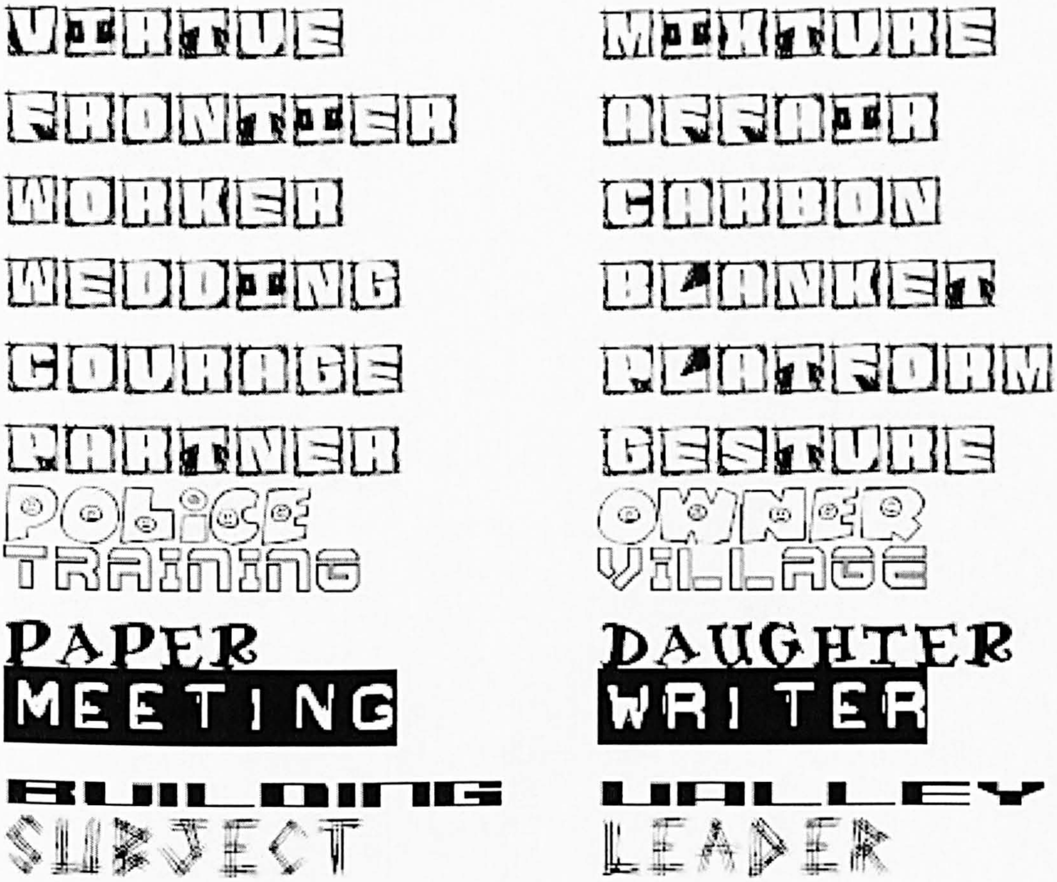


Fig. 1.·an example of the arrangement of word pairs to fonts applicable to all Experiments in the present series. The top 6 pairs share the same font whereas the bottom 6 pairs each have a unique font.

Procedure

Participants were individually tested within one session lasting approximately 30 minutes. Instructions were given to participants on a computer screen before the first trial. Participants were informed that they would be presented with lists containing twelve word pairs, that pairs would be presented one at a time and that the words within each pair would appear on the computer screen, one above the other. They were instructed to learn to associate the words presented and that they would later be given only the top word and be asked to remember the bottom word. The session comprised twelve consecutive lists or learning-test cycles. All word pairs were presented in a white task window centred on an 18 inch monitor at 1024 by 768 screen resolution. Word pairs were presented in '.jpg' format in an Authorware™ runtime application and scaled to similar size, which varied slightly to accommodate legibility, but with a mean size of 140x30 pixels. Each pair remained centred on screen for 3 seconds, with .5 seconds between presentations. The cue word was presented directly above the target word, with a mean of 20 pixels between the words – the mean varying slightly with the height of the specific font. List composition was fixed, i.e. all participants had the same word-pairs in each list. However, the within-list order of pairs and the ordering of lists were randomized for each cycle and for each participant. Once the presentation of a given list was complete, participants proceeded automatically to the testing phase. Participants were provided with a cue word presented in the exact position it had been during the learning phase. The cue word was presented in its original font. A text entry field occupied the space in which the paired associate had originally been presented. Participants were asked to type the word that had been paired with the cue provided. Upon conclusion of a list presentation and testing cycle participants were prompted to click to proceed to the next presentation and testing cycle. This was repeated until all of the lists had been tested.

3.2.1: *Results & Discussion*

The investigation of Experiment 1 was intended to determine the validity of font as an incidental context manipulation in a paired-associate cued recall paradigm. A typical cue overload effect was predicted. Figure 2 presents the proportion correct recall per condition averaged across participants. Participants appeared to have a higher probability of recalling paired associates of words presented in a unique font versus a shared font.

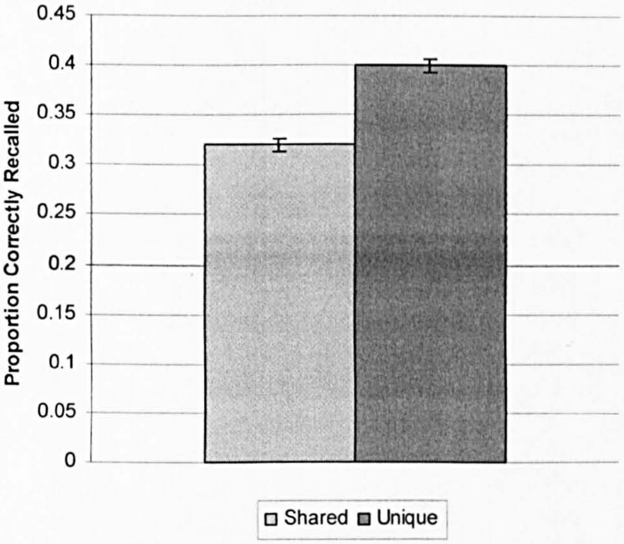


Fig. 2. Mean proportion correct per font condition obtained in Experiment 1 (error bars represent standard error of the mean). Shared represents the condition in which six word pairs per list shared a font. Unique represent the condition in which each word pair had its own unique font.

A paired sample T-test showed that the difference in mean proportion correct per condition was statistically reliable ($t = -4.01$, $p<.001$ [two-tailed], Cohen's $d = .58$) indicating an effect of cue overload for font. The mean proportion of correctly recalled items in the shared font condition was .32 ($\sigma = .14$) versus .4 ($\sigma = .14$) for the unique font condition. When the to-be-remembered items were presented in a font that was shared with other pairs, recall was reliably less accurate than when the pair was presented in a unique font. In other words, the results above indicate that an incidental feature—the font in which words are typed—can enhance recall if it is a unique feature or, relatively speaking, can be detrimental to recall if it is shared with other members of the list.

The results of Experiment 1 show that incidental, contextual retrieval cues can produce a cue-overload effect in a paired-associate cued-recall paradigm. This provided evidence essential for further investigation into memory as discrimination through font. Further investigation necessitated a task in which the level of encoding-retrieval match and cue-overload of context cues could be varied.

A cue overload prediction holds that if multiple pairs are presented in the same font then it will be less effective as part of the retrieval environment at test, resulting in a decline in performance for those pairs (relative to pairs presented in a unique font). Experiment 2 aims to answer the question: what if that font were replaced? If a cue produces a cue-overload effect, then excluding it should be beneficial. Encoding-retrieval match, however, would predict that any reduction in match between encoding and retrieval will be detrimental. If the diagnostic retrieval hypothesis essential to the memory as discrimination view is valid, then replacing the 'overloaded' font with a novel font is expected to be beneficial in this case. It follows that retrieval performance is expected to increase in spite of the decrease in encoding-retrieval match. Experiment 2 investigated this possibility by introducing a novel font condition into the paradigm utilized in Experiment 1. Participants at test were provided with a cue word in either the original font reinstated, or in a novel font.

3.3: EXPERIMENT 2

Participants

City University London students (n = 25) took part in this Experiment. Undergraduates received course credit for participation; graduates received £5. Of these participants 19 were native English speakers whereas the remaining 6 spoke fluent English as a second language.

Materials, Design & Procedure

The words used in Experiment 1 were used again in Experiment 2. The words were arranged into new pairs, and assigned into fourteen new lists of ten pairs each by the same standards as in Experiment 1. As before, word pairs were randomly assigned to either unique or shared font conditions independently for each participant. The order of presentation of lists was also randomized for each participant. Randomization, presentation and user response recording was handled by a purpose-build Microsoft Visual Basic™ 6.0 program. The fonts used for the unique and shared conditions were identical to those used in Experiment 1, with four fonts being excluded randomly due to the difference in number of trials between Experiments.

Participants were presented word pairs in their respective font conditions in a similar manner to Experiment 1. At the time of testing, however, half of the cue words were presented to participants in their original font and half in a novel font. The novel fonts used were derived from the same pool of fonts previously rated in Experiment 1, and the legibility of the fonts did not differ between the shared and unique conditions.

3.3.1: *Results and Discussion*

Experiment 2 was designed to investigate the relationship between encoding-retrieval match and cue overload by an orthogonal manipulation of both. A decrease in encoding-retrieval match is present in the novel font condition, whereas the level of encoding-retrieval match remains unchanged in the reinstated condition. Cue overload is manipulated in a similar manner as Experiment 1: five of the pairs in each list shared the font they were presented in whereas the other five pairs were presented in a unique font. Figure 3 presents the mean proportion of correct recall averaged across participants. As can be seen, participants appear to have a lower probability of recalling a paired associate when a shared font is reinstated than when it is replaced with a novel font. In the unique font condition, there appears to be a slight decline in performance when the novel font is used at test.

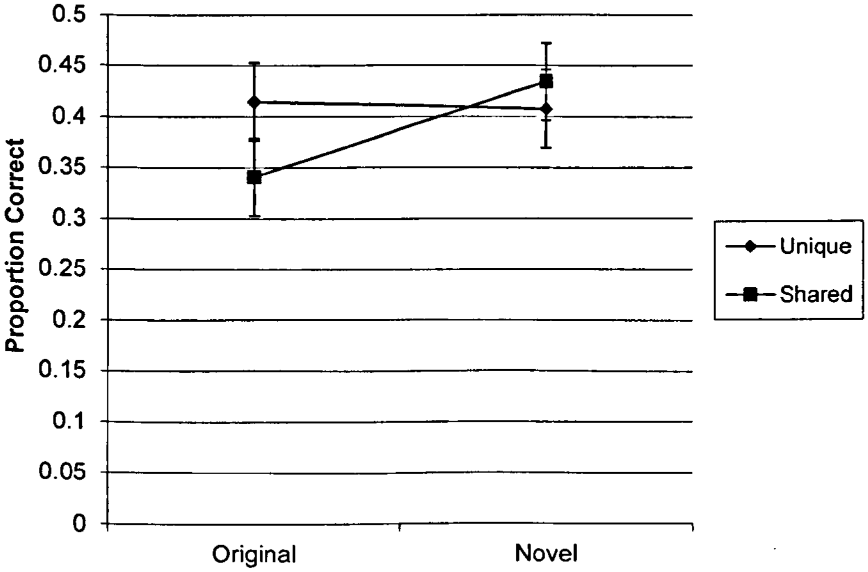


Fig. 3. Mean proportion correct for original and novel font test conditions and the between factor (unique v. shared font) interaction. Shared represents the condition in which six word pairs per list shared a font. Unique represent the condition in which each word pair had its own unique font. Novel pertains to the testing condition in which the word pairs were presented in a novel font at the time of testing. Reinstated pertains to the condition in which word pairs were presented in their originally learned font at the time of testing.

The mean proportion of correct responses for words originally presented in a unique font, and then tested in a novel font was .4 (σ = .24) versus a mean of .41 (σ = .19) for fonts originally shown in a unique font that had that font reinstated at the time of testing. The mean proportion of correct responses for words originally presented in a shared font, and the tested in a novel font was .43 (σ = .17) versus a mean of .34 (σ = .18) for pairs originally presented in a shared font that had that font reinstated at the time of testing. Participants' performance for items with an increase in encoding-retrieval match (the novel font) appears to have decreased in the shared condition. The mean proportion correct per condition was submitted to a repeated measures analysis of variance with two, two-level factors: reinstated/novel test conditions and unique/shared font conditions. The analysis indicated a significant effect of test condition (reinstated/novel) (*F*(1, 24) = 6.72, MSE = .05, p < .01) and a significant interaction (*F*(1, 24) = 2.06, MSE = .014, p = .164). The main effect of font type was not significant (*F*(1, 24) = 14.67, MSE = .026, p < .001). Planned means comparisons revealed a significant difference between unique and shared font conditions when reinstated (*t*(24)= 4.46, p < .001 [two-tailed]), a difference between test conditions for shared fonts (*t*(24)= -4.95, p < .001 [two-tailed]), but no difference between test conditions for unique fonts.

Experiment 2 provides evidence that an effect of cue-overload may be mitigated at the time of retrieval by the exclusion of cues specific to the effect; the findings reveal a 'release from cue overload' effect, so to speak. A clear and classic example of a manipulation of encoding-retrieval match is evident in the test phase of Experiment 2 by way of the novel fonts: such changes in conditions between the time of encoding and the time of retrieval are typically considered as a reduction in encoding-retrieval match. Nevertheless, the evidence suggests that in this case a reduction in encoding-retrieval match can be of benefit.

Experiment 3 attempted to negotiate a different change in encoding-retrieval match within font conditions. At the time of testing in Experiment 3, cue words were either presented in a reinstated font or were displayed in a font that has been associated with another pair within the same list. Words presented in a unique font at the time of encoding were presented at test either in that reinstated font or in a font used in the shared Experimental condition (and *vice versa*). In this way it can be expected under a memory as discrimination view that an effect of cue overload may be effectively transferred to candidates not originally encoded with a shared condition. As an investigation into this in Experiment 3, fonts originally presented with words in the learning phase are either reinstated or swapped with those in the opposite condition.

From an encoding-retrieval match perspective, when words are not presented in their original encoding font there is a reduction in encoding-retrieval match and a decrease in performance would be expected. However, half of the fonts can be expected to produce an effect of cue overload. A memory as discrimination view would predict that the reinstatement of fonts should only be of benefit if the font is diagnostically valuable, i.e. in the unique font condition. The diagnostically harmful, shared fonts were expected to reduce performance when reinstated. If a pair was originally presented in a unique font, but then tested in a shared font it is expected to inherit some of the effect of cue-overload produced by that shared font, reducing the probability of recall for those pairs. Likewise, the pairs originally presented in the shared font are expected to be helped by replacing the shared font with a unique one. The resulting predictions are an increase in performance at test for swapped items in the shared condition along with a decrease in performance for swapped items at test for the unique condition.

3.4: EXPERIMENT 3

Participants

City University London students (n = 25) took part in this Experiment. Undergraduates received course credit for participation; graduates received £5. Of these participants 18 were native English speakers whereas the remaining 7 spoke fluent English as a second language.

Materials, Design & Procedure

The words used in Experiments 1 and 2 were used again in Experiment 3. The assignment of words into pairs, the assignment of pairs into lists and font conditions as well as the ordering of pairs within lists and lists within the Experimental session were all performed again in a manner identical to that of Experiment 2 by a purpose-built Microsoft Visual Basic™ 6.0 program.

Participants were presented word pairs in their respective font conditions in an identical manner to Experiment 2. At the time of testing, however, half of the cue words were presented to participants in their original font and half in a swapped font. A swapped font condition refers to a word pair being assigned a random font from the same list in which it was originally presented, but from the contrasting Experimental condition. In this way a word pair originally presented in a unique font would be presented in a shared font at test and *vice versa.*

3.4.1: *Results*

Experiment 3 was designed to continue the investigations of Experiment 2 by including a different type of manipulation of encoding-retrieval match. In Experiment 3 encoding-retrieval match is reduced when font conditions are swapped at test. Figure 4 presents the mean response time for participants across conditions. Participants appear to exhibit a cue overload effect of font when the font is reinstated, but not when the fonts are swapped.

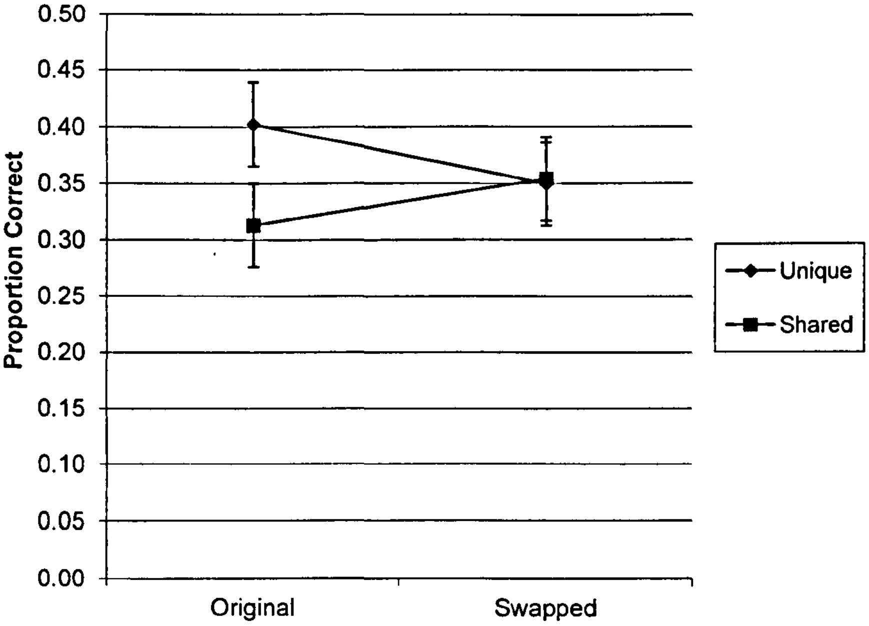


Fig. 4. Mean proportion correct for original and swapped font test conditions and the between factor (unique v. shared font) interaction. Shared represents the condition in which six word pairs per list shared a font. Unique represent the condition in which each word pair had its own unique font. Swapped pertains to the testing condition in which the word pairs were presented in a font from the contrasting condition (e.g. a shared font during learning would receive one of the unique fonts) at the time of testing. Reinstated pertains to the condition in which word pairs were presented in their originally learned font at the time of testing.

The mean proportion of correct responses for words originally presented in a unique font, and then tested in a shared font was .35 (σ = .19) versus a mean of .40 (σ = .19) for fonts originally shown in a unique font that had that font reinstated at the time of testing. The mean proportion of correct responses for words originally presented in a shared font, and the tested in a unique font was .35 (σ = .20) versus a mean of .31 (σ = .19) for pairs originally presented in a shared font that had that font reinstated at the time of testing. Participants' performance for items with an increase in encoding-retrieval match (the shared font) again appear to have decreased in the shared condition. The mean proportion correct per condition was submitted to a repeated measures analysis of variance with two, two-level factors: test condition (reinstated/swapped) and font condition (unique/shared). The analysis indicated a significant effect of font condition ($F(1, 24) = 7.11$, MSE = .044, $p < .05$) and a significant interaction ($F(1, 24) = 12.84$, MSE = .056, $p < .01$). The main effect of test condition was non-significant. Similar to the results of Experiment 2 the effect of cue overload exhibited in the font condition is partially eliminated by the non-reinstatement of the font at the time of retrieval. Planned means comparisons revealed a significant difference between unique and shared reinstated fonts ($t = 6.21$, $p < .001$ [two-tailed]) but no difference between unique and shared fonts in the swapped test condition ($t = .19$, $p > .5$ [two-tailed]). The beneficial effect of reduced encoding-retrieval match was significant, in that a difference is revealed between shared font reinstated and shared font swapped conditions in a planned means comparison ($t = 2.4$, $p < .05$ [two-tailed]). Additionally, a reliable difference was found between unique font reinstated and unique font swapped ($t = 2.63$, $p < .01$ [two-tailed]).

3.5: General Discussion

The present series investigated the relationship between encoding-retrieval match and cue overload. Experiment 1 revealed a significant advantage in cued-recall of paired associates when those pairs were learned and later presented in a unique font versus a shared font; the latter showed a cue-overload effect. A 'release of cue-overload' effect was demonstrated in Experiment 2: pairs learned in a shared font were equally well remembered to those learned in a unique font if the shared font was replaced at test with a novel font. Experiment 3 demonstrated that an effect of cue-overload attributable to a shared font can be effectively transferred to pairs originally learned in a unique font; pairs learned in the unique font condition, presented in the shared font at test, were less well-remembered than the same items presented in their original font. Likewise, in Experiment 3, the replacement of a shared font with a unique one produced an increase in performance, replicating the findings of Experiment 2.

Experiment 1 made a novel contribution in that it was the first to demonstrate a font cue-overload effect in a cued recall paradigm. The font cue-overload effect was replicated in Experiments 2 and 3, and novel contributions were made in those Experiments by way of demonstrating how reductions of encoding-retrieval match can interact with the cue-overload effect. The data indicate that the highest probability of correctly retrieving the appropriate target is conditional upon the diagnostic relationship between the target and its retrieval cue. In those situations in which the encoding involved a unique font, reinstatement of those conditions led to higher retrieval probability; this effect is predicted by both encoding-retrieval match and memory as discrimination viewpoints. In those situations in which the encoding environment contained a shared font, reinstatement led to a reduced probability of correct retrieval. It should be noted, however, that fonts were not randomly assigned to conditions. It was decided that as poor legibility of a given font could have a greater effect in the shared condition than unique, some Experimenter intervention would be necessary to ensure that the fonts used in the shared condition were legible. As such, fonts were rated and assigned to shared and unique conditions. However, as all participants in the series utilized these same materials this could be seen as a confound.

The manipulation of font in the present series represented a change in the incidental context. An encoding-retrieval match view would predict that this context was a condition of the encoding environment which, if reinstated, would be beneficial to retrieval as it would increase the probability of specifying the appropriate retrieval candidate. Encoding-retrieval match seems to be a secondary consideration to cue overload in the data of the present series in that increases in encoding-retrieval match only lead to increased performance when the increase came without the addition of cue-overload. When considering trace-cue compatibility in terms of feature overlap, it is easy to identify situations in which a bare minimum amount of cueing is sufficient for recall. An everyday example would be recalling a wide range of memories about a person having been given only their name as a cue. Once a sufficient amount of cueing has been achieved the appropriate target can be recalled. Any superfluous cueing may have no effect, but it may also serve to increase the probability of confusion with competing memory traces. That potential for increased confusion probability is central to the memory as discrimination view.

Relying on a basic assumption of the accuracy of an encoding-retrieval match view may lead to appropriate predictions by correlation, but if encoding-retrieval match is not representative of the retrieval mechanism then potential confounds may arise. A vast body of literature relies heavily on the basic encoding-retrieval match assumption. The data of the present series contributes to a new and growing body of evidence that suggests that encoding-retrieval match may be a corollary effect belying the complete picture. A diagnostic relationship between cue and target encompasses the theory that an increase encoding-retrieval match may be irrelevant to recall, while simultaneously stipulating that the increase in match should not accompany an increase in cue overload.

Chapter 4:

Encoding-retrieval match and cue-overload in response time

4.1: Introduction

A large body of literature continues to rely heavily on the encoding-retrieval match principle to make predictions and interpret findings (Toth & Hunt, 1999; but see Nairne, 2002; Poirier *et al,* in Press). According to encoding-retrieval match, retrieval performance in memory tasks is expected to increase proportionately to the degree of match between the conditions at the time of encoding and the conditions at the time of retrieval (Tulving, 1979). For proponents of encoding-retrieval match, other effects on retrieval performance may be considered circumstantially. One such effect is cue overload, or the effect by which retrieval performance is expected to decrease as the number of potential retrieval candidates associated with a retrieval cue increases (Watkins & Watkins, 1975; Craik & Jacoby, 1979). The fan effect (e.g. Anderson, 1974) can be thought of similarly as it describes the effect by which retrieval performance for facts declines as the number of facts associated with that topic increases.

Although the original investigations into encoding-retrieval match and cue overload took place over three decades before the present series there are still many questions to be answered about these two oft-cited effects, and only recently has any published attempt been made to investigate the relationship between them. Prompted by Nairne's (2002) article reflecting on the logic of a pure encoding-retrieval match view a number of investigations have been made into what has been termed memory as discrimination (Poirier *et al*, in Press; Fowler, Poirier, Koutmeridou & Davelaar, submitted). The memory as discrimination view suggests that a diagnostic relationship between the target and its retrieval cue is necessary for optimal retrieval performance. According to that view, an increase in the encoding-retrieval match can be seen as irrelevant, in that it will only be beneficial if it is not outweighed by an increase in cue overload. This may be indicative of a retrieval mechanism in which encoding-retrieval match does not play a role. Empirical data presented in Poirier *et al* (in Press) indicated that in circumstances in which cue overload is permitted to have an effect, that effect can overcome the influence of encoding-retrieval match.

The purpose of the present investigation was to determine the contribution of cue-overload and encoding-retrieval match effects in response time versus proportion of correct responses. Further, that these are measured in a situation in which both encoding-retrieval match and cue-overload are orthogonally manipulated. Three regression equations were fit to the data of the present study, as well as to the data of three Experiments previously reported in Poirier *et al* (in Press). Of these equations, one equation represents a cue-overload process, one an encoding-retrieval match process, and one an even contribution of encoding-retrieval match and cue-overload processes. Response time was chosen as a means of investigation due to the fact that the use of correct trials ensures that participants have successfully learned the material. The predictions of the memory as discrimination view as offered by Nairne (2002) do not make any stipulations as to a difference between probability of correct recall and response time measures. It is intuitive to consider the possibility that an increase in retrieval performance would mean a decrease in response time in addition to a decrease in recall probability. Let it be assumed that when a cue is perceived, a search through a portion of memory is initiated, with the size of the search set being determined by the number of candidates associated with the retrieval cue (e.g. Fowler, Poirier, Davelaar & Koutmeridou, submitted). Under this assumption, how do cue-overload and encoding-retrieval match effects influence response time? The following sections of this paper address this question through the regression analyses of the findings of a series of empirical studies. The tasks involved in each of the studies presented here varied in terms of stimulus and response mode, but the general design remained consistent.

A cued-recognition paradigm designed to allow for a contrast between the effects of encoding-retrieval match and cue-overload was employed. Each Experiment consisted of a training phase in which participants learned to associate two or three cues with a to-be-remembered (TBR) target item, and a test phase in which only one or two of the cues were presented on each trial. Some of the cues were associated with more than one target (shared cues) and the remaining cues were associated to a single target (unique cues). The manipulation of the number of cues present at the time of testing represented a manipulation of the degree of match between encoding and testing conditions; the presence or absence of a shared cue at test represented a manipulation of cue-overload. This basic design, utilized across all Experiments, allowed an orthogonal manipulation of encoding-retrieval match and cue-overload. A novel Experiment of this type is reported as Experiment 1, along with a review of three Experiments previously reported in Poirier *et al* (2010). The general prediction of Experiment 1 is that cueing conditions involving a shared cue will result in a decline in performance relative to conditions involving only unique cues, even when that condition involves a high level of encoding-retrieval match.

4.1.1: Cue-overload

In a task in which participants were asked to select a target amongst k candidates, let n be the number of candidates considered before finding the target. If α is the mean time—across multiple trials—required to make a single cue to candidate comparison, then the total search time is αn. Adding the time required for the participant to perceive the cues and physically respond (q), the total response time (RT) for a task can be represented by equation 1.

$$RT = q + \alpha n \qquad (1)$$

Consider that n would be most directly related to the number of candidates cued in a given trial. As an example, under a serial, self-terminating search assumption, n would be best described by equation 2, in which max$k$ is the number of candidates cued (the level of cue-overload).

$$n = \frac{1 + \max k}{2} \qquad (2)$$

It is assumed the search is self-terminating, (i.e. the search is interrupted when a response is identified). Hence, the use of the mid-range to determine the value for n in a serial search mechanism seems reasonable. If the presentation of trials in a series were not random, then across trials it may be that certain biases in search order (i.e. some retrieval candidates may be considered first) may arise. A weighted average equation considering biases may be more appropriate for calculating the value of *n* in other tasks. If equation 1 can adequately account for changes in average response time depending on conditions it would imply that the effect of cue-overload (excluding encoding-retrieval match) is sufficient to explain the effect of cueing conditions. Equation 1 relies on a single, serial search taking place with the perception of a retrieval environment. Under this model, it is expected that an increased level of cue-overload would lead to a larger search set, thus increasing the time required to complete the search.

4.1.2: Encoding-retrieval match

The effect of increasing the level of match between conditions at encoding and conditions at testing has long been thought to increase performance, but performance is somewhat of a general term. Response time is a factor of performance, but how is an increase in encoding-retrieval match expected to increase performance by reducing response time? It could be assumed that an increase encoding-retrieval match reduces the number of possible candidates for retrieval. It could also be assumed that it increases the activation of certain memory traces, giving them an advantage in speed and effectively reducing the amount of time required to conclude that process. Both of these (along with a number of other possibilities) can be taken into account through a simple representation of encoding-retrieval match.

When considering response time the diffusion model is an appropriate consideration (Ratcliff, 1978). However, for the sake of parsimony a simple regression model is proposed for the present analysis. If α is the mean time required to make a single cue to candidate comparison as in equation 1, and if the process of making a cue-target comparison is adjusted by an increase in encoding-retrieval match, then let α (1-*r/e*) represent the time required to make a single cue-target comparison when *e* is the number of features of the target originally encoded and *r* is the number of features of the cue that match the target at the time of retrieval. The greater the degree of match, the lower the value of α . The calculation of response time considering only encoding-retrieval match would then be represented by equation 3.

$$RT = q + \alpha(1 - r / e) \tag{3}$$

The predictions of equation 3 represent the fundamental stipulation of the encoding-retrieval match principle: that as the degree of match between the conditions at the time of encoding match the conditions at the time of retrieval, the greater the retrieval performance. If considered as predictive of performance in response time measures this means a simple reduction in response time. In equation 3 the time required to make a cue to target comparison (α) is reduced by a ratio of match between conditions at encoding to conditions at retrieval. No amount of cue-overload is considered in equation 3. As such, it can be thought that the reduction in time required to process a given cue-target relationship in equation 3 is indicative of the 'head start' that the search receives as a result of a greater amount of evidence being provided by the retrieval cue, thus beginning the search closer to the sufficient criterion threshold for selection as the most likely retrieval candidate.

If the contribution of both cue-overload and encoding-retrieval match were to be simultaneously considered, the complete calculation of response time could be represented by equation 4, in which *n* is defined by equation 2.

$$RT = q + \alpha n(1 - r / e) \tag{4}$$

The calculations in equation 4 reduce the time required to make a single cue to target comparison as the level of encoding-retrieval match increases, while increasing the number of cue to target comparisons to be made in the search as the level of cue-overload increases. Equation 4 suggests that increases in encoding-retrieval match may be nullified by an increase in cue-overload, and *vice versa*. Equation 4 can also predict that an increase in encoding-retrieval match may lead to a reduction in performance should the effect of cue-overload (n) outweigh the effect of encoding-retrieval match (1-r/e).

In order to generate a data environment within which to test these predictions, Poirier *et al* (in Press) presented an Experimental paradigm in which cue-overload and encoding-retrieval match varied orthogonally across conditions. The paradigm of Poirier *et al* is replicated in Experiment 1 of the present series. The replication was performed in an effort to produce both response time and proportion correct response data. In Poirier *et al* participants were trained to a high criterion in order to produce the greatest possible amount of response time data. Although response time data was also collected for the present series, the training phase of Experiment 1 in the present series set a lower criterion for acceptable proportion of correct responses in order to continue to the testing phase. This was designed to eliminate ceiling effects in the data and permit an analysis of a proportion of correct responses as well as response time.

4.2: EXPERIMENT 1

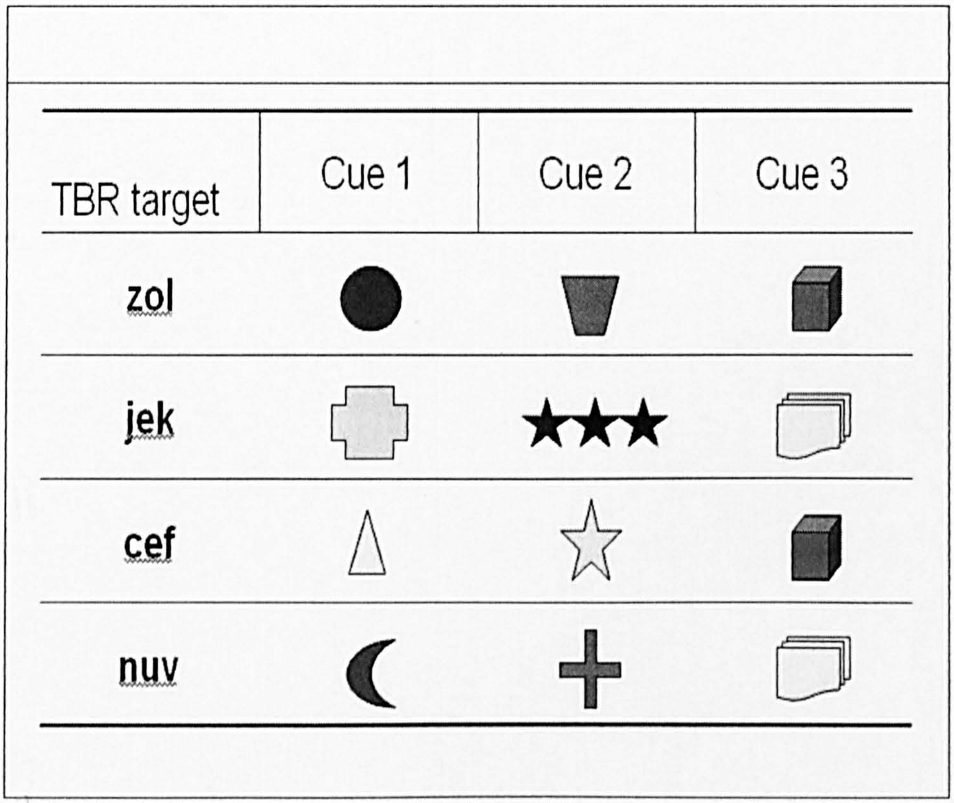
Participants

City University London undergraduate students (N = 27) participated for course credit.

Method

A cued-recognition task was employed, in which participants were asked to associate consonant-vowel-consonant (CVC) non-words to arrays of shapes. A total of eight CVCs were used in the Experiment. The CVCs were assigned to one of two groups of four CVCs, balanced for neighbourhood size and frequency (Figure 1). The shapes were centred in 170 by 140 pixel white squares. The shapes varied in colour and dimension but were similar in size. A purpose-built Adobe Authorware™ software program was used to randomize the presentation order, display the shape arrays and CVCs, and to record participant response times to the nearest hundred milliseconds.

Shapes were assigned to arrays in such a way that each array contained two shapes unique only to that array, and one shape which would be shared with one other array. These were presented in random order and participants were instructed that they were to remember the combination of shapes rather than their arrangement.



TBR target	Cue 1	Cue 2	Cue 3
zol	●	▼	■
jek	✚	★★★	❐
cef	△	☆	■
nuv	☾	✚	❐

Fig. 1. Displays an example of possible cue to target associations in Experiment 1.

Partial arrays of shapes would allow for four testing conditions: 'one unique,' 'one shared,' 'one unique plus one shared,' or 'two unique.' This design allowed for an orthogonal manipulation of encoding-retrieval match and cue-overload. For example: the 'one unique' versus 'two unique' condition represented a manipulation of encoding-retrieval match - the 'two unique' versus 'one unique plus one shared' condition represented a manipulation of cue overload. A pure encoding-retrieval match view would predict that the two conditions with the greater degree of encoding-retrieval match ('two unique' and 'one unique plus one shared') would exhibit the greater performance – in this case, the fastest response time and greatest proportion of correct responses. A pure cue-overload prediction would be that the conditions with the least amount of cue-overload ('one unique' and 'two unique') would exhibit the best response time. A diagnostic retrieval prediction in which both cue-overload and encoding-retrieval match are equally viable in the orthogonal design would be that increased encoding retrieval match produces reduced response time only insofar as it is not accompanied by an increase in cue overload, hence: 'two unique' is expected to exhibit the fastest response time, and 'one unique' and 'one unique plus one shared' are expected to remain more or less equal, given that the increase in encoding-retrieval match for 'one unique plus one shared' is accompanied by an increase in cue-overload.

Procedure

Participants were tested individually in a noise-resistant cubicle. Test sessions lasted approximately 25 minutes. Participants were instructed that they would be learning to associate shapes with ‘nonsense syllable names,’ and that they would later be asked to identify the appropriate name of a set of shapes given only a partial set. Participants were provided with two training phases, both of which involved the presentation of stimuli followed by a practice test. In a training phase participants were presented with a full array of three shapes. The shapes were presented in a horizontal array centred at the top of the computer screen (see Figure 1). The associated CVC was presented below the array in the centre of the screen (see Figure 1). Each array and its CVC remained on the screen for four seconds, followed by a 1.5 second interval before the presentation of the next (Figure 2). Once all four arrays and CVC associations had been presented six times, participants were tested.

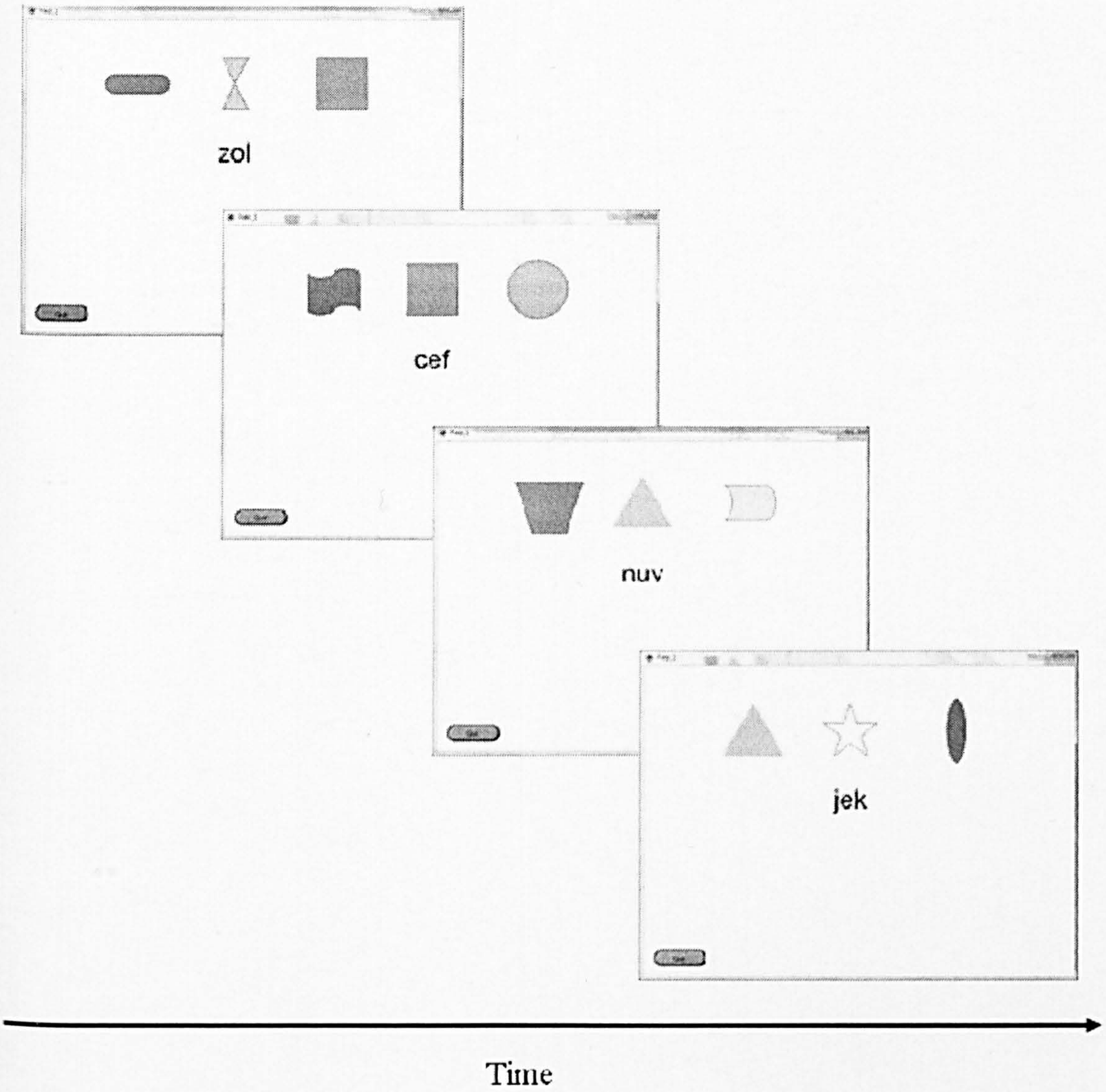
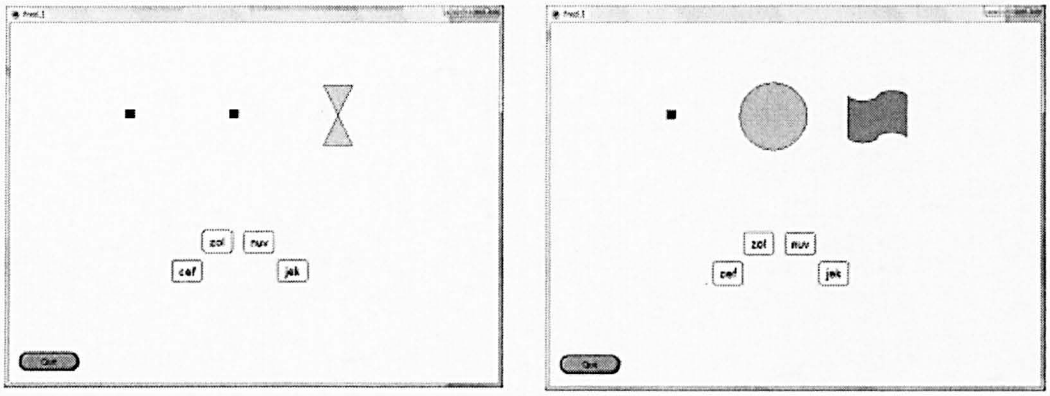
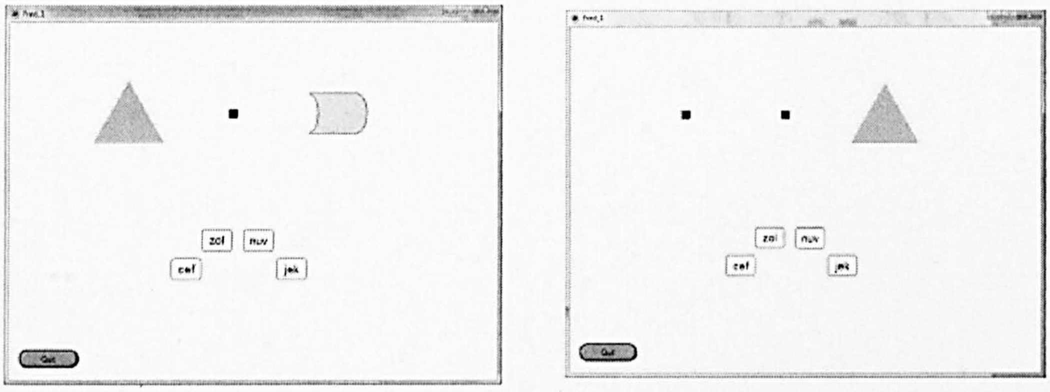


Fig. 2. The way in which stimuli were presented over time in the training phase of Experiment 1. The actual shape to CVC name assignments are indicated by Figure 1.

The practice testing during the training phase involved presentation of the full array of shapes in random order. For example: the presentation of 'JEK' in Figure 1 as being associated with an array containing a triangle, a star, and an oval (in that order) may be represented in a practice test as being a star, an oval and a triangle (in that order, or any other randomized order). Participants were not aware that the practice test was part of the training phase. All four possible CVCs were presented in a semi-circular array in the centre of the screen (Figure 3). The mouse pointer appeared in the centre of the CVC array, and participants were instructed to click on the appropriate CVC for the array. The mouse pointer appeared at the centre of this array at the start of each trial, equidistant from each of the CVCs. The use of a mouse may not have been optimal as the requirement of hand-eye coordination may have introduced some noise into the data. The use of a simple interface (such as a 4 button key pad) might be preferable for future studies. However, this noise is not expected to impact a particular variable in the present study.



Left panel – one-unique cue example; right panel two-unique cues examples



Left panel – one-unique-plus-one-shared cue example; right panel, one-shared cue.

Fig. 3. The four possible cueing scenarios in the testing phase of Experiment 1, with the CVC response options displayed toward the bottom of the screen and the cue array toward the top.

Upon completion of two such training phases (including presentation and practice testing) participants were tested in two test cycles. In a test cycle, a random selection of one or two shapes was provided for participants. The shapes presented would belong to one of four testing conditions: ‘one unique,’ ‘one shared,’ ‘one unique plus one shared,’ or ‘two unique’. After 32 test trials the participants were given another training phase. A further 32 test trials were then presented, for a total of 64 trials. All conditions were tested equally often. The positions of the cues were determined randomly *via* software. Missing cues were replaced by a dash (Figure 3). The inclusion of the ‘one shared’ condition merely tested participants’ knowledge of the shared cues, but was not included in response time analyses due to the fact that there were two correct responses for that condition.

4.2.1: *Results & Discussion*

The results include analyses of response time and proportion correct measures. The data included in the response time analysis was for correct responses only. Participants who scored fewer than 60% correct overall in the task were not included in the response time analysis (24 of the 27 participants met this criterion). An accuracy criterion of 90% for inclusion in the analysis results in 21 of the 27 participants being included and does not change the pattern of results, but does reduce the power of the analysis. Proportion of correct responses data were calculated as a simple mean for all participants per condition. A criterion of at least 30% correct was adopted for inclusion in the proportion of correct responses data, and all 27 participants met this criterion. With regard to response time - a pure cue-overload prediction would be that the ‘one unique (1u)’ and ‘two unique (2u)’ conditions exhibit the best response times, due to the ‘one unique plus one shared (1u1s)’ condition containing the highest degree of cue overload.

That prediction seems supported by the data presented in Figure 4, indicating a mean response time of 1.49 (σ = .31) seconds for the 1u condition, 1.48 (σ = .41) seconds for the 2u condition, and 1.79 (σ = .67) seconds for the 1u1s condition.

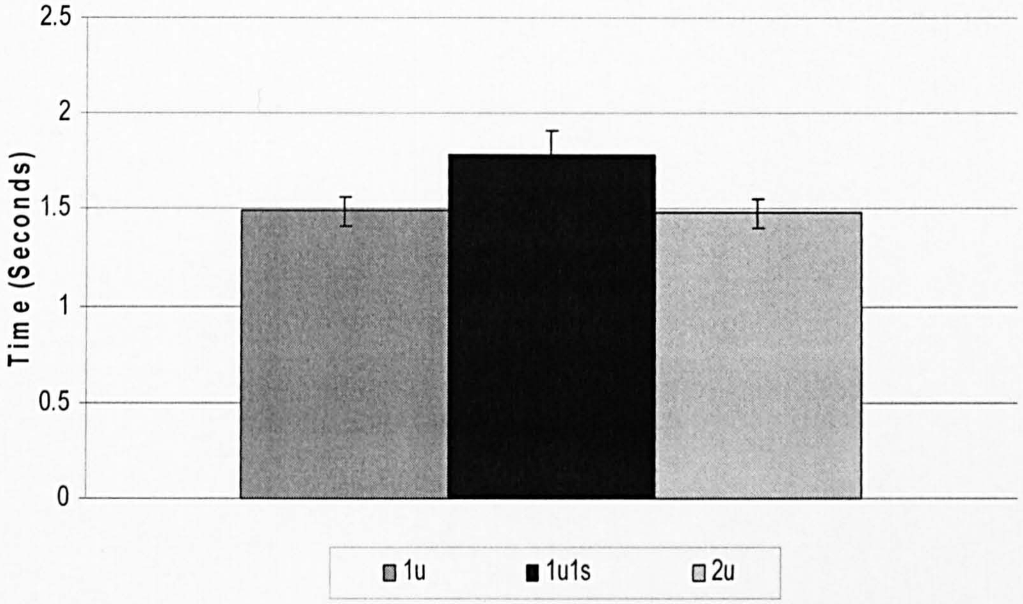


Fig. 4. Mean response times (in seconds) for conditions in Experiment 1. The label of the chart indicates the cueing conditions at the time of testing: 1u = one unique feature. 1u1s = one unique and one shared feature. 2u = two unique features. Error bars show standard error of the mean.

The within-subjects analysis of variance showed a significant main effect of cue condition, $F(2,46) = 7.815$, $p < 0.001$. Planned means comparisons showed a difference between the 1u and 1u1s conditions $t(23) = 2.915$, $p < 0.004$ (1-tailed) and between the 2u and 1u1s conditions $t(23) = 3.109$, $p < 0.0025$ (1-tailed) (with the 1u1s condition producing a higher response time than both the 1u and 2u conditions). No difference was found between the 1u and 2u conditions. These results are surprising in that no effect of encoding-retrieval match is evident in the data, in this case ruling out the encoding-retrieval match and diagnostic retrieval equations as viable fits to the data (full analysis of fit below).

Participants that met the 60% accuracy criteria of inclusion in the response time data also produced adequate data for an analysis of the proportion of correct responses. A diagnostic retrieval hypothesis indicative of the memory as discrimination view would predict that one unique cue (1u) should result in a significantly lower proportion of correct responses than two unique cues (2u), but significantly more than one unique plus one shared cue (1u1s). That trend is present in Figure 5.

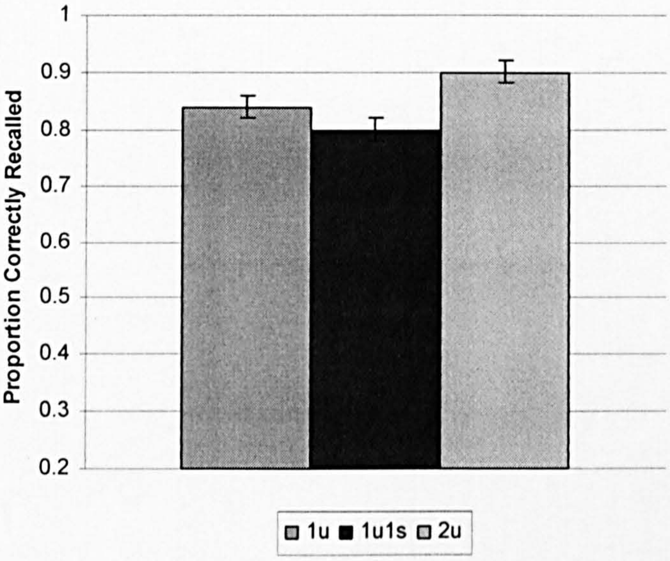
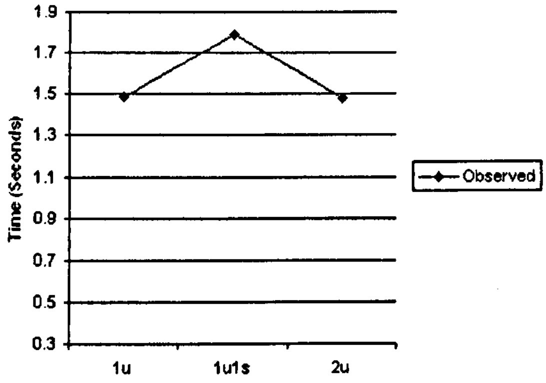
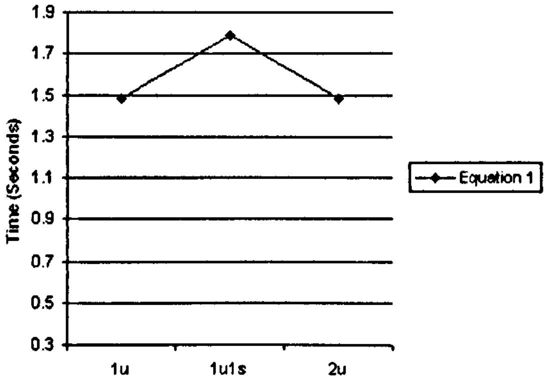


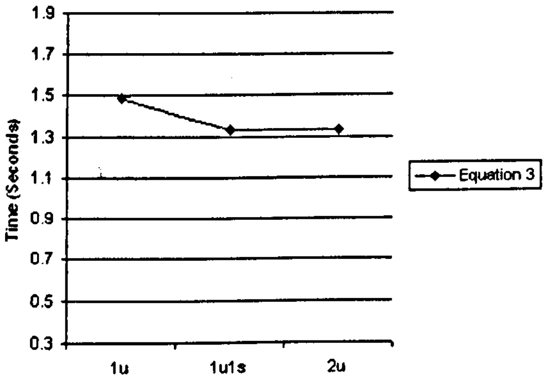
Fig. 5. The mean proportion of correct responses for cue conditions in Experiment 1. The label of the chart indicates the cueing conditions at the time of testing: 1u = one unique feature. 1u1s = one unique and one shared feature. 2u = two unique features. Error bars show standard error of the mean.

The mean proportion of correct responses was .84 (σ = .10) for the 1u condition, .8 (σ = .10) for the 1u1s condition and .9 (σ = .09) for the 2u condition. The participants' proportion of correct responses was fit to a one way, repeated measures ANOVA, and showed a significant main effect of cue condition $F(2,46) = 11.16$, $p < 0.001$. Planned means comparisons revealed a significant difference between the 1u and 1u1s conditions $t(23) = 2.120$, $p = 0.044$ (1-tailed) indicating that participants provided significantly fewer correct responses in the 1u1s condition than in the 1u condition. A significant difference was found between the 2u and 1u1s conditions $t(23) = -4.774$, $p < 0.001$ (1-tailed), indicating that fewer correct responses were made in the 1u1s condition than the 2u condition. A significant difference was also found between the 1u and 2u conditions $t(23) = -2.582$, $p = 0.015$ (1-tailed) indicating significantly fewer correct responses in the 1u condition than the 2u condition. In this way, the proportion of correct participant responses in the present series reflected the memory as discrimination view. The 2u condition, representing a greater level of encoding-retrieval match than 1u (but with no difference in the level of cue-overload) is the most diagnostically valuable under the memory as discrimination view, and exhibited the highest proportion of correct responses. The 1u1s condition, with the same level of encoding-retrieval match as the 2u condition (but with the addition of cue-overload with the presence of a shared feature) exhibited the lowest proportion of correct responses. This suggests that an increase in encoding-retrieval match from the 1u condition may result in an increase in performance (the 2u condition) or a decrease in performance (the 1u1s condition).

Although the diagnostic retrieval predictions indicative of a memory as discrimination view were reflected in proportion correct measures in the present series as well as in previous Experiments (Fowler, Poirier Koutmeridou & Davelaar, submitted), that effect does not seem to be found in response time measures such as those in the present study. An effect of cue-overload seems to prevail in the response time data of the present study in spite of the manipulation of encoding-retrieval match and its effect on the proportion of correct responses. Data fits were undertaken to both the present study and the Poirier *et al* (in Press) data. The equations described above were each employed. In a typical regression equation of the form $y = X\beta + \varepsilon$, the Experimental variable (n, r/e, or the product of both) was determined by the set of conditions in the testing environment. In determining a value for *n,* the number of items associated with the retrieval cue at the time of testing for that condition would be added to 1 then divided by 2. For example, using this method a 1u1s (one unique and one shared) condition would receive the *n* value of 1.5 as there are 2 retrieval candidates associated with the retrieval cue in that condition and (2+1)/2=1.5. In calculating an *r/e* value the number of cue features present at the time of retrieval *r* is divided by the number of features present at the time of encoding *e*. In the event of the 1u1s condition the number of cue features equals 2 at the time of retrieval. As there were 3 features originally present in the learning phase the value of *e* is equal to 3, for an *r/e* value of 2/3. Using those values as predictor variables in a linear regression analysis against mean values derived from observed data per condition, the β and ε values were revealed and the final prediction calculated as y. Observed data values were the overall means across participants for each condition. The linear regression analysis was then run for the predictor values against the three means (1u, 1u1s and 2u conditions). This was done for each of the three equations described above.







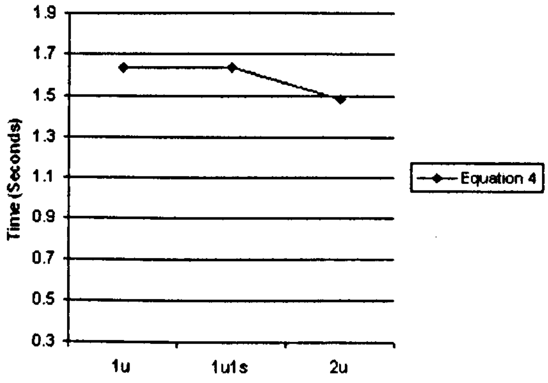


Fig. 6. Predicted response times of the aforementioned equations and observed values of Experiment 1. For each point in each graph: 1u is one unique feature present at the time of testing; 1u1s is one unique and one shared feature present; 2u is two unique features present. The observed values of Experiment 1 appear in the top left graph. The predictions of equation 1 appear in the top right graph. The predictions of equation 3 appear in the bottom left graph. The predictions of equation 4 appear in the bottom right graph.

The observed values presented in Figure 6 represent the overall means for all participants which reached criterion in each of the conditions from Experiment 1 and were compared to the base predictions of the three regression equations presented above. Equation 1 represents a pure cue-overload prediction. Equation 3 represents a pure encoding-retrieval match prediction. Equation 4 represents an equal contribution of cue-overload and encoding-retrieval match.

From the regression equations the free parameters of each regression equation were derived: the value of the ε value was used as the value of q (representing the time required to perceive a cue and physically respond), and the value of the beta parameter was used as α (representing the time required to make a single cue to candidate comparison in a search). The pure cure-overload equation (equation 1in Figure 6) was a significant fit to the response time data of Experiment 1 $R^2 = .99$, $\beta = .31$ $t(2) = 38, p <$ .01. The other two regression equations (one representing pure encoding-retrieval match, the other a diagnostic retrieval representation) did not approach significance in fit to the response time data obtained from Experiment 1. For equation 3, the pure encoding-retrieval match equation, $R^2 = .23$; for equation 4, the diagnostic retrieval equation, $R^2 = .27$. This is perhaps not surprising given that the response time data in Experiment 1 so closely exemplifies a pure cue-overload result. However, it should be considered that perhaps a subtle effect of encoding-retrieval match may be present, but countered by the time required to process an additional cue in the two cue conditions, relative to the one unique condition. If two cues are present in a given trial (i.e. the 2u condition) participants have two shapes to attend to on the screen. This could be expected to cause some increase in response time. If an effect of encoding-retrieval match were to decrease response time these two effects may counter one another. An effect of attending to an additional cue could be expected to result in an increase in the intercept of the regression equations in the present analysis, indicative of the time required for participants to perceive the cues and physically respond. An analysis of the intercept values derived through regression (q in equations 1, 2 and 3) did not reveal such an effect of an increase in number of cues from 1 to 2 (1u versus 2u conditions).

The case studies presented in the following section were chosen from Poirier *et al* (in Press) as the stimulus types and responses mode used across studies were quite different from the present study. Differences in stimulus type and response mode may be expected to result in changes in the intercept of each of the regression equations, but should not be expected to result in differences in the observed values of the effects of manipulating cue-overload or encoding-retrieval match. In this way it is predicted that the amount of time required to make a single cue to target comparison (α) should remain constant across all Experiments as this value is representative of a cognitive process. The number of comparisons necessary to conclude the search (*n*) should be expected to vary according to the level of cue-overload present at the time of retrieval, and thus be dependent upon Experimental conditions. The other factors of response time involved in the Experiment pertain to stimulus type and/or response mode, and in that way these factors should only result in changes to the intercept of the regression equations. A consistent result for the α value across Experiments would lend further support to an equation's representation of the processes involved in memory retrieval.

4.3: CASE STUDIES

General Methods

The three regression equations above were fit to the data of three Experiments previously reported in Poirier *et al* (in Press). As the present study (described above) was designed as a variation of the studies from Poirier *et* al, the Experiments presented in this section utilized a general methodology similar to that of the present study.

Poirier et al Experiment 1

The task in Experiment 1 of Poirier *et al* (in Press) was to associate an array of three simple shapes with a consonant-vowel-consonant (CVC) nonsense-syllabic name

(WUX, ZEK, RIZ, CEF). At test participants were provided with a partial array of either 1 or two shapes and asked to click the appropriate CVC name in the array with their mouse. Experiment 1 of the present series was a replication of Poirier *et al* Experiment 1; however the Poirier *et al* Experiment set a higher criterion to proceed from the training to testing phases, which resulted in a greater amount of response time data but no informative data for the proportion of correct participant responses as proportion correct was over 60% in all conditions.

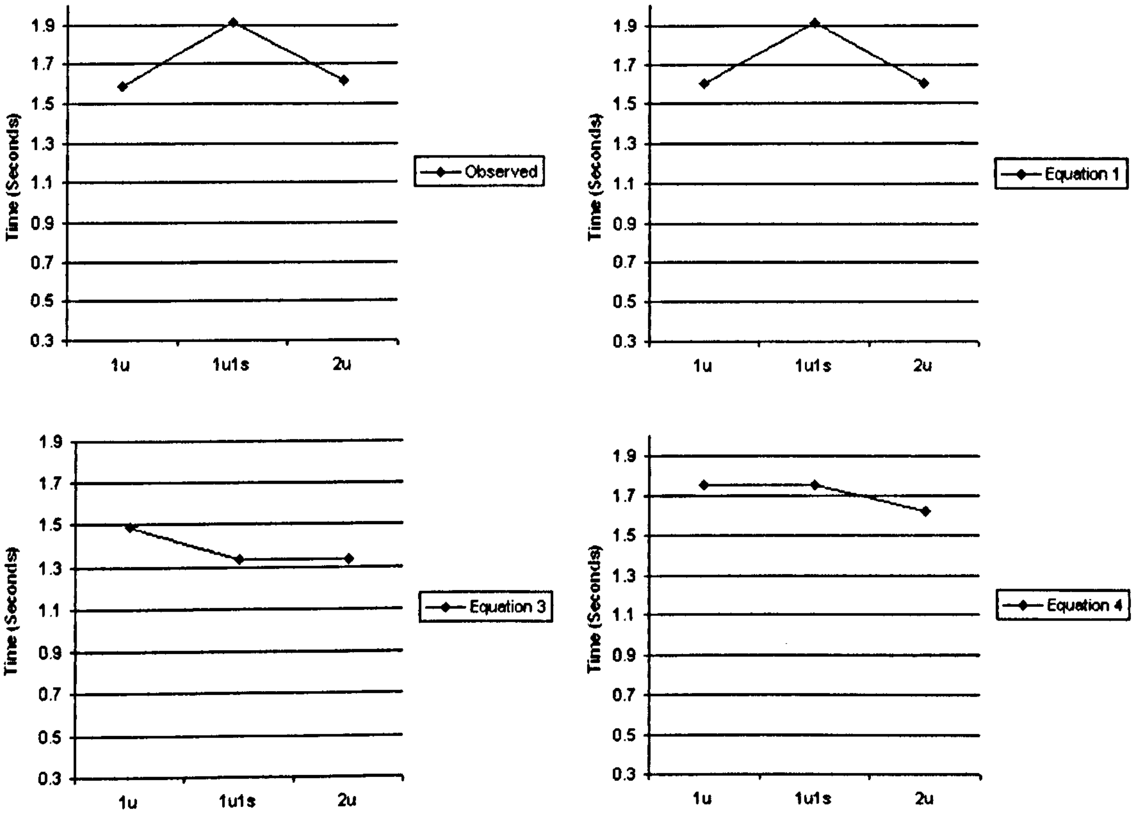


Fig. 7. Predicted response times of the equations presented in the present analysis and observed values of Poirier *et al* Experiment 1. For each point in each graph: 1u is one unique feature present at the time of testing; 1u1s is one unique and one shared feature present; 2u is two unique features present. The observed values of Experiment 1 appear in the top left graph.

The predictions of equation 1 appear in the top right graph. The predictions of equation 3 appear in the bottom left graph. The predictions of equation 4 appear in the bottom right graph.

The data from Poirier *et* al Experiment 1 was fit to all three regression equations in the same manner as the data from the previous Experiment. Equation 1 represents predictions of the pure cue-overload regression equation. Equation 3 represents the pure encoding-retrieval match regression equation. Equation 4 represents the equal contribution of encoding-retrieval match and cue-overload. The Observed line represents the within participant means of the Experiment. Again the pure cure-overload equation (Equation 1, in Figure 7) was a significant fit to the data of Poirier *et al* Experiment 1, $R^2 = .99$, $\beta = .29$ $t(2) = 38$, $p = .05$. The other two regression equations did not approach significance. For Equation 3, the pure encoding-retrieval match equation, $R^2 = .34$; for Equation 4, the diagnostic retrieval equation, $R^2 = .16$.

Poirier et al Experiment 2

The task in Experiment 2 of Poirier *et al* (in Press) was designed to extend the same manipulation as Experiment 1 to more ecologically valid stimuli. Instead of associating arrays of shapes with CVCs, participants were asked to associate common names typically given to people with adjectives typically used to describe people.

Table 1. Example of the cues and targets called upon in Experiment 2.

Targets	Cue 1	Cue 2	Cue 3
Luke	Mild	Gentle	Bright
Anna	Elegant	Open	Lazy
Sophie	Chaotic	Fair	Bright
James	Clumsy	Kind	Lazy

The choice of names and adjectives in Experiment 2 meant that as compared to Experiment 1 the cues and targets were more familiar, more concrete, and more meaningful. Participants were expected to have some prior exposure of the names used, as well as the adjectives. The number of targets and the number of cues used in Experiment 2 were the same as Experiment 1 in that participants were asked to learn four names and their associated adjectives. Three adjectives were associated with each name, with one adjective being shared amongst two names, and the other two adjective unique to its associated name.

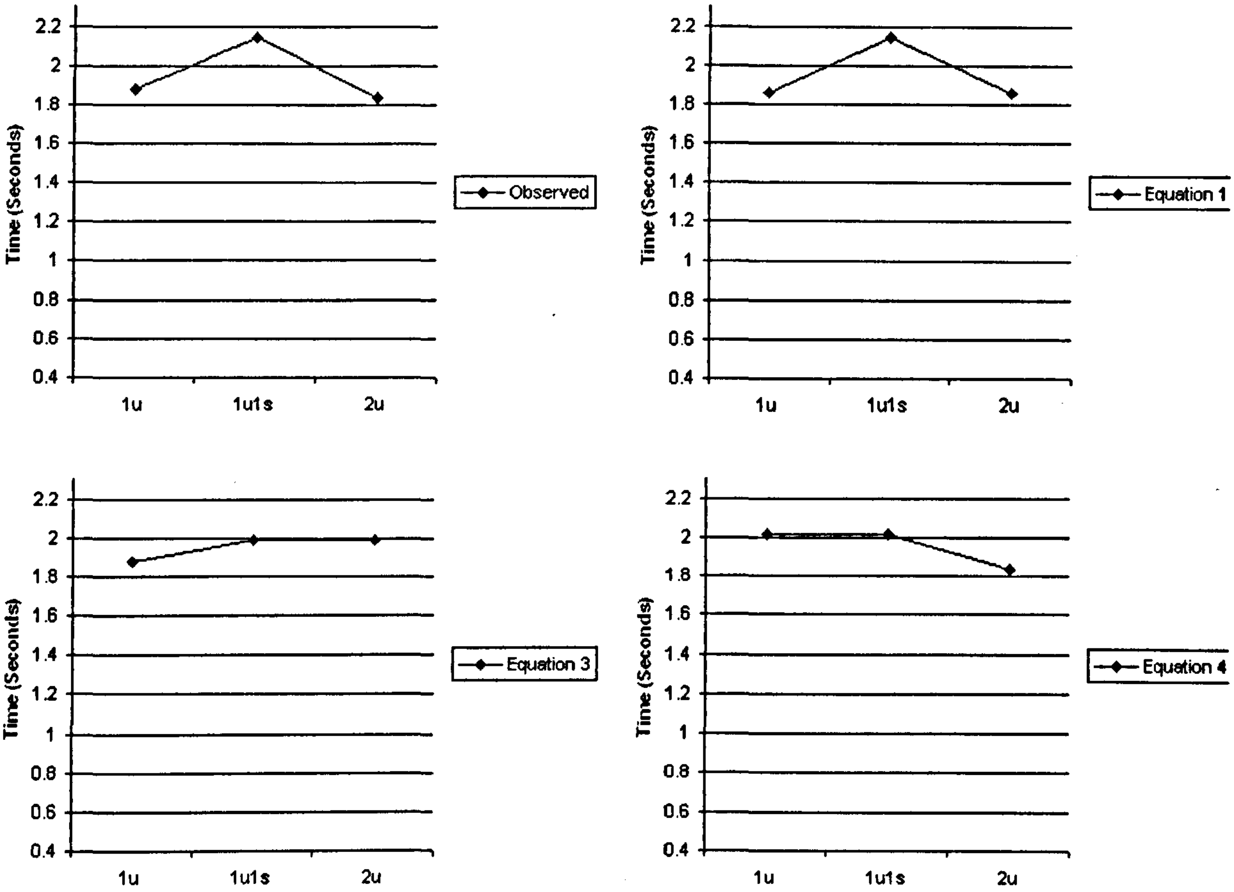


Fig. 8. Predicted response times of the above method, and observed values of Poirier *et al* Experiment 2. For each point in each graph: 1u is one unique feature present at the time of testing; 1u1s is one unique and one shared feature present; 2u is two unique features present. The observed values of Experiment 1 appear in the top left graph. The predictions of equation 1 appear in the top right graph. The predictions of equation 3 appear in the bottom left graph. The predictions of equation 4 appear in the bottom right graph.

When fit to the regression equations, the data from Poirier *et al* Experiment 2 continued to demonstrate the trend exhibited from the present study and from Poirier *et al* Experiment 1 in spite of the methodological changes and increase in grand mean response times across all conditions. Equation 1 represents predictions of the pure cue-overload regression equation. Equation 3 represents the pure encoding-retrieval match regression equation. Equation 4 represents the equal contribution of encoding-retrieval match and cue-overload. The Observed line represents the within participant means of the Experiment. The pure cure-overload equation (equation 1, line *a* in Figure 8) explained a large amount of variability in the data of Poirier *et al* Experiment 2, $R^2 = .98$, $\beta = .29$ $t(2) = 38$, $p = .08$, but was marginally significant in the β t-test. The other two regression equations did not approach significance. For Equation 3, the pure encoding-retrieval match equation, $R^2 = .15$; for Equation 4, the diagnostic retrieval equation, $R^2 = .37$.

Poirier et al Experiment 4

The final Poirier *et al* (in Press) paper contains four Experiments. However, at the time in which this chapter was written it contained three. When the fourth Experiment was included in Poirier *et al* it was positioned as Experiment 3. As including the new Experiment 3 would not significantly enhance the content of the analysis of this chapter it was not included. As such this chapter continues with the analysis of Poirier *et al* Experiment 4. Experiment 4 of Poirier *et al* was designed to both extend the test of ecologically valid stimuli, and to test the counter-intuitive prediction that a complete set of cues (the full array of cues initially present at learning) may be detrimental relative to a partial cue in a cued recognition task. Participants were asked to associate pictures of farm animals with pictures of fruit 'preferred' by the animals. Participants were required to associate three animals with two fruits each – i.e. there were only three possible responses in Experiment 4, relative to the four possible responses in the preceding Experiments.

Table 2 – Sample target and cue combinations as called upon in Experiment 4.

Target	Cue 1	Cue 2
Pig	Pear	Apple
Sheep	Strawberry	Banana
Cow	Grapes	Banana

With only two possible cue features (the two fruit), the task became much less complex. One of the fruit was shared amongst two animals, and all other fruit were unique to the associated animal. In this regard, one animal was associated two unique fruit and the other animals were paired with one unique plus one shared fruit. These changes resulted in a task that was expected to be significantly easier for participants to complete.

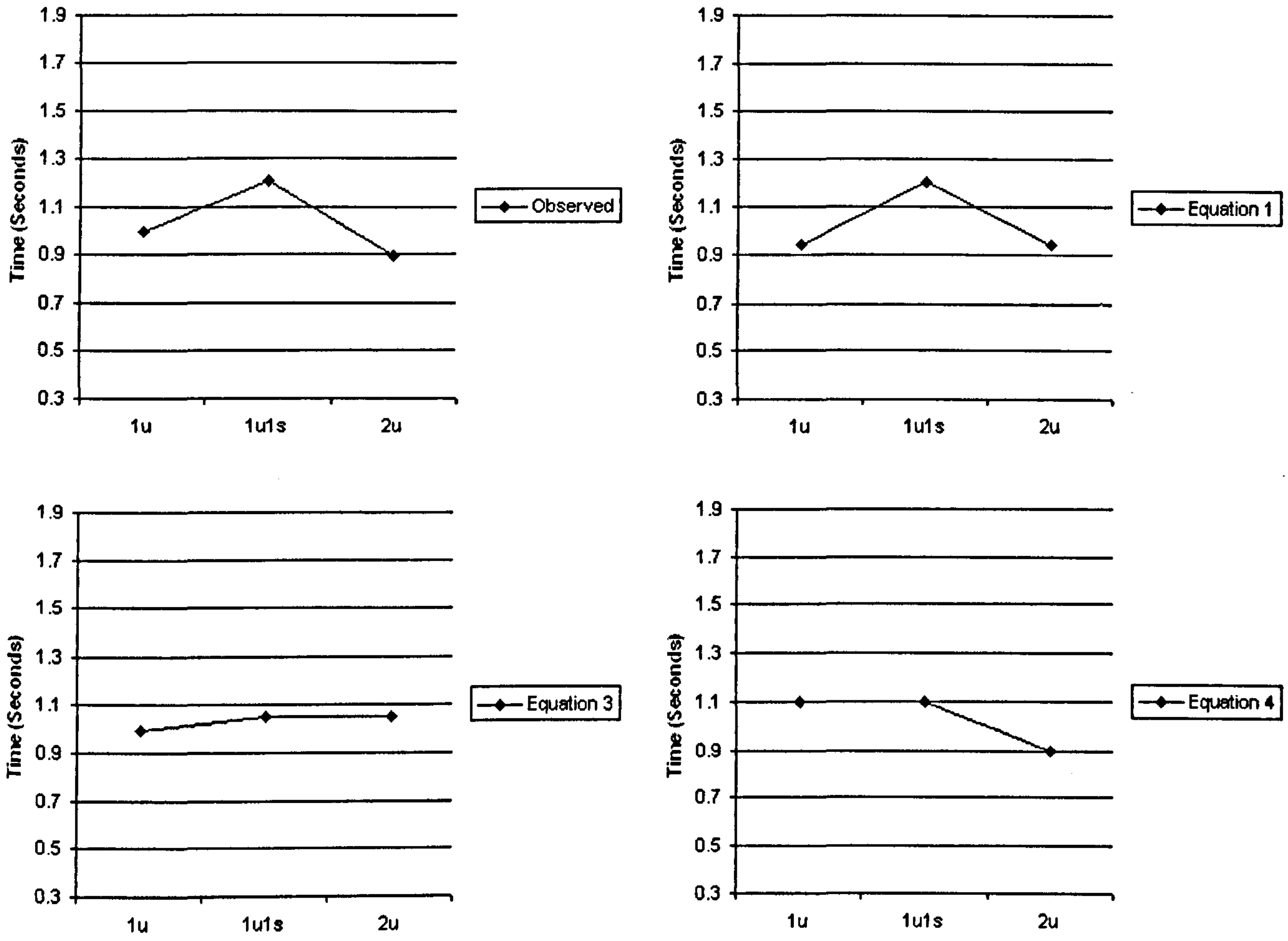


Fig. 9. Predicted response times of the equations presented herein and observed values of Poirier *et al* Experiment 4. For each point in each graph: 1u is one unique feature present at the time of testing; 1u1s is one unique and one shared feature present; 2u is two unique features present. The observed values of Experiment 1 appear in the top left graph. The predictions of equation 1 appear in the top right graph. The predictions of equation 3 appear in the bottom left graph. The predictions of equation 4 appear in the bottom right graph.

With regard to Figure 9 – equation 1 represents predictions of the pure cue-overload regression equation. Equation 3 represents the pure encoding-retrieval match regression equation. Equation 4 represents an equal contribution of both cue-overload and encoding-retrieval match. The Observed line represents the within participant means of the Experiment. The pure cue-overload regression equation's data fit continues to explain a large portion of the variability when fit to Poirier *et al* Experiment 4, $R^2 = .91$, $\beta = .27$ $t(2) = 3$, $p = .19$, however the β t-test is non-significant. Still, the pure cue-overload regression equation remains a good fit as compared to the other two regression equations, which neither approach significance, nor explain the variability in the data as well. For equation 3, the pure encoding-retrieval match equation, $R^2 = .04$; for equation 4, the diagnostic retrieval equation, $R^2 = .55$.

4.4 *General Results &Discussion*

The fits of the regression equations across four Experiments are displayed in table 3. Each regression equation was designed to represent only the core principle of its respective viewpoint: equation 1 was written to represent cue-overload alone – equation 3 was written to represent encoding-retrieval match alone – equation 4 was written to represent a combination of the two in which each has equal weight – representing a simple case of diagnostic retrieval, in which retrieval performance is expected to increase to the extent that the retrieval cue is capable of identifying a single target for retrieval to the exclusion of all others. The memory as discrimination view holds to a diagnostic retrieval hypothesis. The pattern of results expected of a diagnostic retrieval hypothesis was reflected in the proportion of correct responses reported here. It was not represented in response time measures. Instead, the data presented here, as well as that of Poirier *et al* (in Press) (a total of four response time measures of Experiments in which encoding-retrieval match and cue-overload are orthogonally manipulated) yield no indication of encoding-retrieval match contributing to a reduction in response time. In effect, when encoding retrieval match was increased, for example when going from one unique cue to two unique cues, no change in response time was detectable. The diffusion model (e.g. Ratcliff, 1978) could be applied to capture these data.

It seems surprising that response time data derived from a series of Experiments in which cue-overload and encoding-retrieval match are manipulated orthogonally did not produce data that demonstrate contributions of both cue-overload and encoding-retrieval match. This is of particular interest in that the manipulation of encoding-retrieval match did yield a result in the proportion of correct responses. In the present series described above (see Figure 2), the proportion of correct responses data follows a pattern one would expect from memory as discrimination predictions with an orthogonal manipulation of encoding-retrieval match and cue-overload present. Specifically in the data presented in Figure 2 the 1u condition shows inferior retrieval performance to the 2u condition, but greater performance than the 1u1s condition. Although the equations presented in this chapter describe response time, if they were fit to the data in Figure 2 one would expect that equation 3 (representing an equal contribution of encoding-retrieval match and cue-overload) would be the best fit. Using the typical regression equation (i.e. Equation 1) as an example, the q value could be considered the base line for retrieval, and could be set as 1. The n value could be derived in the same way as for response time, proportionate to cue-overload (as per equation 2). In the case of proportion of correct responses, the *n* value could be considered inversely proportionate to retrieval likelihood, and would be made negative. The alpha values would be derived from linear regression as in the application of the equations to response time. With this framework of using these simple models to account for a proportion of correct responses the remaining two equations would fulfil their appropriate duties. Retrieval likelihood would be expected to decrease proportionate to cue-overload with Equation 1, be expected to increase proportionate to encoding-retrieval match as per Equation 3, and be expected to consider both equally as previously with Equation 4. Figure 10 demonstrates this fit.

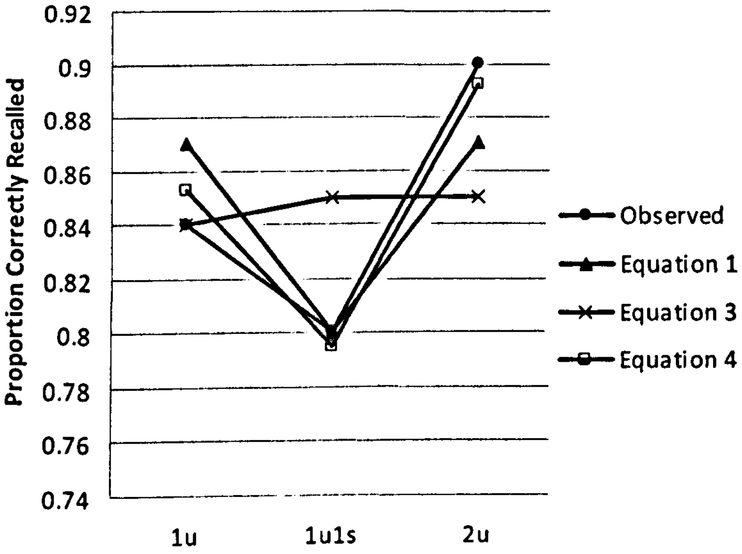


Fig. 10. The observed proportion of correct responses from the present series (Experiment 1, Figure 2) compared to predictions generated using equations 1, 3 and 4.

Figure 10 presents the observed values of Experiment 1 of the present series (Figure 2). As in the previous comparisons of the present series, equation 1 represents predictions of the pure cue-overload regression equation. Equation 3 represents the pure encoding-retrieval match regression equation. Equation 4 represents an equal contribution of both cue-overload and encoding-retrieval match. The observed values and three equations are presented in the same graph (Figure 10) in this instance because the pattern of predictions is similar between equations 1 and 4. Figure 10 shows that equation 4 appears to more closely resemble the observed values than equation 1. Equation 4 statistically comes closest to predicting the observed data, $t(2) = 38$, $p < .01$, $R^2 = .95$, versus an R^2 value of .65 for equation 1 and an R^2 value of .01 for equation 2. This may indicate that a set of predictions considering both cue-overload and encoding-retrieval match may be more appropriate for measures of the proportion of correct responses than for response time measures.

Regard to response time, the data of the present study as well as all Experiments included from Poirier *et al* (in Press) point to a pure cue-overload explanation. A simple regression equation of the cue-overload effect (equation 1) is shown to be the best fit amongst the equations of the present study with a mean R^2 value of .97 as demonstrated in Table 3. This may suggest that the *time* required to search through memory may be a monotonically increasing function of cue-overload and independent of encoding-retrieval match. Although the data generated by these Experiments is insufficient for a formal analysis of goodness of fit, the present analysis serves to provide qualitative evidence that cue-overload may be the only mechanism at work in determining performance in response time measures.

Table 3 R squared results by equation

	a	b	c	d	Mean
Equation 1	0.99	0.99	0.98	0.91	0.97
Equation 3	0.23	0.34	0.15	0.04	0.19
Equation 4	0.27	0.17	0.37	0.55	0.34

Table 3 shows the R^2 values by Experiment: a) Experiment 1 (present study) b) Poirier *et al* Experiment 1 c) Poirier *et al* Experiment 2 and d) Poirier *et al* Experiment 4, across the three equations used as regression equations: equation 1) pure cue-overload, equation 2) pure encoding-retrieval match and equation 3) diagnostic retrieval. What is also of note is the consistency of the effect as evidenced by the β values derived from regression. With respect to equation 1, the β value remained virtually unchanged across four Experiments. Figure 11 presents the grand means of the average time to respond in a trial, across conditions, for the four Experiments considered here. The grand mean values change, probably owing to methodological differences in stimulus and response types. Yet, as is seen in Figure 11, the β values across Experiments for the regression of Equation 1 remain nearly constant. The average β value across four Experiments was .29, with a standard deviation of .017 (β = .31 for the present Experiment, .29 for Experiment 1, .29 for Experiment 2 and .27 for Experiment 4 for Poirier *et al*). The β values were input as the α free parameter of all three regression equations.

In terms of a process, one interpretation of the value of the α parameter in equation 1 was that it is indicative of the time required to process a single cue to target relationship. Cue-overload was represented as the number of such comparisons required before finding the target, a value that would increase as the number of possible targets in the search increases. A consistent α value of approximately .29 translates into an approximate 290 millisecond time required to process such a comparison regardless of whether the stimuli are shapes/non-words, names/adjectives or animals/fruit.

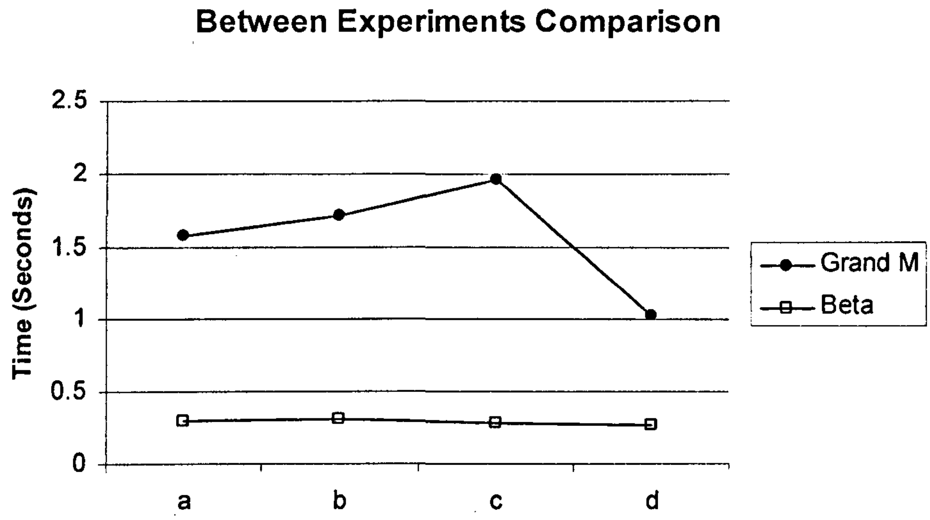


Fig. 11. Displays the predicted values for the parameters *r* and α , and the observed grand mean response times of each Experiment reported. - a) Experiment 1 of the present series - b) Poirier *et al* Experiment 1 - c) Poirier *et al* Experiment 2 – d) Poirier *et al* Experiment 4.

The memory as discrimination view typically lends some support to the encoding-retrieval match principle in that memory as discrimination stimulates that an increase in encoding-retrieval match should have a positive effect on performance insofar as that increase is not accompanied by an increase in cue-overload. With that in mind, the result of the analyses in this chapter indicate that encoding-retrieval match may play only a minor role in response time measures for correct trials. However, with regard to the present analyses, encoding-retrieval match shows no beneficial effect on response time.

4.4.1: *Summary*

The object of the present series was to investigate possible interactions between encoding-retrieval match and cue-overload effects through a more formal representation. Three regression equations were fit to data of the present study as well as those previously collected in Poirier *et al* (in Press): an equation representing the process of cue-overload, an equation representing the process of encoding-retrieval match, and an equation representing a combination of cue-overload and encoding-retrieval match. Analyses revealed that the equation with the best fit was that which represented cue-overload alone. The present analyses suggest that when correct retrieval is achieved the only contributing factor to the duration of the search process is that of cue-overload. In this way the present analyses support the idea that the minimum amount of cueing required to successfully retrieve a target is most likely to result in the fastest response time.

Chapter 5:

Modelling Discrimination

5.1: Introduction

One of the most widely-held views regarding how information is recalled from our past is that performance is related to the encoding-retrieval match, or the degree to which conditions at the time of encoding match the conditions at the time of retrieval (Dewhurst, 2010; Nairne, 2002, 2005; Tulving, 1979). A clearly documented and well-known addendum to encoding-retrieval match predictions is the effect of cue-overload; this effect shows that retrieval performance decreases as the number of candidates associated with the retrieval cue increases (Watkins & Watkins, 1975). The predictions derived from the effect of cue-overload compete with those based on encoding-retrieval match when a simple question is asked: What happens when an increase in encoding-retrieval match also means an increase in cue-overload? This can happen when the elements responsible for an increase in encoding-retrieval match also recruit a number of new retrieval candidates. It would be easy to conclude that depending on the circumstances, one would be more influential than the other. However, this leaves open the question of which circumstances lead to the dominance of cue overload or encoding-retrieval match. Generally concluding that encoding-retrieval match and cue-overload together form an adequate explanation means the predictions as to the outcome of the retrieval process are left undetermined and vague.

Previous work has suggested that successful retrieval depends not only on the power to identify an adequate retrieval candidate, but also on the capacity to exclude incorrect competing candidates (Hunt, 2003). The memory as discrimination view, championed by Nairne (2002), proposes that a *diagnostic* relationship between the cue and the target is necessary to maximize retrieval performance. Nairne defined a diagnostic cue as one that heightens the probability that the correct retrieval candidate will be identified *from amongst competing traces.* In such a definition the only factor for consideration in generating predictions is the degree to which a cue specifies a target. This can be considered independent of the level of encoding-retrieval match, thus rendering the level of match irrelevant to predictions under a memory as discrimination view. A better diagnostic relationship could be obtained *via* any increase in encoding-retrieval match that does not lead to an increase in cue overload; the most diagnostic relationship could be construed as the greatest amount of encoding-retrieval match attainable with zero effect of cue-overload (i.e. leaving only one, well-specified candidate for retrieval). The present paper offers a means of quantifying the nature of a diagnostic retrieval process through the identification of those circumstances in which increases in encoding-retrieval match are ineffective or detrimental to retrieval performance.

Many researchers have argued that forgetting can be seen as discrimination failure, or even that all memory retrieval is a discrimination task (Capaldi & Neath, 1995; Hunt, 2003; Hunt & Smith, 1996; Nairne, 2002). As mentioned above, under a memory as discrimination view, the likelihood of retrieving the correct item is related to the ease with which one is able to discriminate between the correct memory and other retrieval candidates. Forgetting as discrimination failure can be seen as a retrieval cue being ineffective in the task of specifying a retrieval target such that it may be retrieved. These viewpoints rely heavily on cue-overload, with attention given to distinctiveness effects, biases or other such effects that allow a given retrieval candidate to stand out amongst its competitors, making it the most likely candidate for retrieval (Hunt, 2003). Poirier *et al* (in Press) and Fowler, Poirier, Koutmeridou & Davelaar (submitted) presented evidence that an increase in encoding-retrieval match may have no effect, or indeed have a detrimental effect on retrieval performance; this was true whether performance was measured through probability correct or response time. These studies indicate that as encoding-retrieval match increases, a probabilistic determination must be made as to whether or not that increase is of benefit to retrieval. In other words, this work shows that increasing the encoding retrieval match may (depending on cue-overload) lead to an in increase in performance, a decrease in performance, or a null effect (Nairne, 2002, 2005).

This paper aims to provide a means of quantifying the relationship between encoding-retrieval match and cue-overload; the end result is expressed as a probability of correctly recalling a target given a retrieval cue. As such, the work serves as an existence proof that if the memory as discrimination ideas are expressed precisely, the predictions they generate do lead to an apt description of the possible relationship between the effects of encoding-retrieval match and cue-overload observable in data.

Nairne (2002) described a thought Experiment in which clear exceptions to encoding-retrieval match are exemplified. The thought Experiment involved cues that were composed of multiple, separable features. For a given cue, some features were unique to a single retrieval candidate, but others were shared amongst multiple retrieval candidates. It follows that the optimal retrieval environment would be one in which only a partial encoding-retrieval match were present: a cue with all of the shared features excluded would be more effective than a more complete match that included the features shared with competitors. Experimental studies such as provided by Poirier *et al* (2010) put Nairne's (2002) thought Experiment to the test and the data support the idea that a diagnostically valuable retrieval cue can be more effective than one in which a greater degree of encoding-retrieval match is present. The present article will elaborate on the nature of a diagnostic retrieval process by examining how the encoding-retrieval match and cue-overload principles might contribute.

5.2: *Computation Comparison*

In terms of raw search capacity, a computer is able to generate thousands, if not millions of results for a search in under a second, with exclusions being made perfectly by virtue of the characters in the search query. In a situation in which there are thousands of potential candidates, how would a human brain fare? Consider a set of two retrieval cues, both associated with the same target in memory. Cue *a* would (if presented alone) restrict a search to a portion of memory, set *A*; cue *b* (if presented alone) would restrict a search to a portion of memory, set *B*. The intersection of *A* and *B* may be referred to as set *C*. The sizes of sets *A* and *B* would be representative of the level of cue-overload produced by the processing of cues *a* and *b* respectively. If a computer were performing a search and was presented with *a*, then a complete *A* would be formed. If the computer were then presented with *b*, the search would produce a complete set *C*, with no intrusions from members of *A or B* that do not belong to *C*. If $|C| = |A|$ then the inclusion of the second cue, *b*, was ineffective. If $|C| < |A|$ then the inclusion of *b* was beneficial. For a computer, there are no other possible outcomes of including two retrieval cues versus one. After all, when a computer narrows a search based on new input there is no chance of items from outside of the search results jumping in by virtue of some features shared with the query. A human might make such a mistake.

A computer would be immune to a change in $|B|$. No matter how large B becomes, the capacity for a computer to reduce the number of potential retrieval candidates to C is unchanged. If a human being were performing a memory search based purely on encoding-retrieval match then there would be no confusion errors due to increase in cue-overload, i.e. the increase in the set of candidates associated with any part of a cue.

A computer search involves listing all those items in computer memory which contain all the features of the search query. With each new feature of the cue in a computer search, a new search is performed listing only those items which contain all of the features. In humans, however, there is a probability of including an item in a memory search even when it would have been logically eliminated. This may be because a human memory search does not simply involve listing those items in memory which contain all of the features of the cue – human memory also involves a search through items which need to be rejected by the search (e.g. Hunt, 2002). Considering human memory retrieval - when cue a is presented set A forms because members of A are sufficiently similar to a to be part of the retrieval set. When presented along with cue b, the object of the search at that point is to form the intersection of sets A and B, set C. As such, members of $\{A - B'\}$ would need to be purged from the search set and members of $\{B - A'\}$ need to be preserved. In both of these processes there is a probability of error. That probability of error should be proportional to the similarity of those should-be-rejected members of B to the retrieval cue as per the encoding-retrieval match principle. It can be reasonably expected that the probability of a retrieval error should also be related to the number of items considered in the search. Hunt (2003) suggests that similarity between items in a retrieval environment creates a context within which distinctiveness effects may appear. Although the focus of Hunt's paper was distinctiveness, of interest in representing similarity judgments should be this context of similarity suggested by Hunt. According to Hunt - as similarities between items are considered those similarities generate a context which allows for distinctiveness effects. However, it could also be suggested that in the absence of a distinctive item that same context of similarity increases the similarity of all of those items to a potential retrieval cue. Without a distinctive item present, the similarities between items lower the relative similarity of a potential retrieval cue to the appropriate target. This reduction in relative similarity is the focus of the present model, and as such the present model can be referred to as the relative similarity model. When considering relative similarity between the cue and the target in a search, the similarity of items to the cue should be considered within the context of the search set size.

The consideration of similarity relative to other items under simultaneous consideration can be referred to as relative similarity. With that in mind, the consideration of similarity between two items with no other factors can be referred to as absolute similarity. Although a computer may consider the absolute similarity between candidates to be the only factor for inclusion in the search set, it has been put forward that human memory uses relative similarity (e.g. Hunt, 2003) . Modelling the human retrieval process should consider similarity in a way that allows for the size of the search set to adjust similarity accordingly. The retrieval model presented as part of this chapter will provide a means of modelling within context. In this way, the following model represents idea that similarity comparisons can only be made within the context of other similarity comparisons.

5.3: Retrieval Model

If the degree to which conditions at encoding match conditions at test is causally and monotonically related to retrieval performance, then a simple quantitative representation of that concept should lead to appropriate predictions. If the encoding-retrieval match comparison can be thought of as taking place in a psychological space represented geometrically as an *m*-dimensional Euclidean vector space, then each cue and each target can be thought of as a vector in a 2-dimensional plane. This type of representation of the cue-target comparison has been used previously in a number of well-known memory models (e.g. Bower, 1967; Estes, 1980; Hintzman, 1986; Murdock, 1983; Nairne, 1990). If conditions at encoding and at testing are both represented as separate vectors, then any disparities between the vectors can be taken as mismatches and a distance metric based on the latter would be:

$$d = \frac{\sum_{k=1}^{N} | x_{Qk} - x_{ik} |}{N} \tag{1}$$

Equation 1 is the distance metric offered by Shepard (1987). It represents the concept of mismatching conditions by describing the distance (*d*) between a cue (*Q*) and a target (*i*) in a psychological space. This is represented as the sum of the absolute value of the difference between the cue and target vector values (x) over the total number (N) of features (k) compared. Shepard's distance metric has been used widely in determining the difference between items in memory (e.g. Nairne, 2005; Nosofsky & Bergert, 2007; Surprenant, Neath & Brown, 2006). In this regard it is not the number of differences but the proportion of mismatch. A simple example of this is given below, where each feature is binary.

$$\text{Example: If } \begin{matrix} c_1 = (1,0,0) \\ t_1 = (0,1,0) \end{matrix} \text{ then } d = \frac{2}{N}$$

The two vector values in the example above differ for 2 of 3 features, so simply speaking the distance between them is 2/3. Shepard (1987) suggests that distance (d, equation 1) be transformed into similarity by the method shown in equation 2. As Shepard's algorithm considers the similarity between two items with no other factors (as there was no need in Shepard's work to do otherwise), it can be referred to as the absolute similarity model.

$$s(Q_1, i_1) = \exp(-d(Q_1, i_1)) \tag{2}$$

The degree of similarity between the cue and the target (equation 2) can be seen as representative of the degree of match between conditions at the time of encoding and the conditions at the time of retrieval. With that in mind, equation 2 is a model of encoding-retrieval match. As the output of equation 2 is naturally limited to values between 0 and 1, the probability of successful retrieval under a strict application of the encoding-retrieval match principle is proportional to the value of *s*. Although equation 2 may be an over-simplification of encoding-retrieval match, it does serve to isolate the core of the principle. Encoding-retrieval match at its core considers the relationship between a retrieval cue and the target exclusively.

Equation 2 is the similarity transformation employed to convert the distance value (*d*) into a similarity value (*s*) for any cue (*Q*) to item (*i*) relationship. This has been widely utilised as a means of transforming distance in psychological space to a similarity measure (e.g. Nairne, 2005; Surprenant, Neath & Brown, 2006).

If it can be allowed that competing memory traces should be considered in generating predictions of retrieval performance, then it is a natural extension that some competitors are more likely to be confused with the target than others. To incorporate this, it is important to consider the similarity (*s*) between the cue and the target, as well as the similarity between the cue and all other possible targets.

However, the utilisation of the similarity metric as written in equation 2 has a disadvantage. Similarity as represented *via* equation 2 relates distance *d* (equation 1) to similarity in the same fashion regardless of the number of similarity comparisons to be made. As a measure of absolute similarity it may not be able to represent human similarity judgments when cue-overload is a factor. However, as with the memory as discrimination view as offered by Nairne (2002), when the size of the search set increases the relative similarity of the cue to any given member of that set decreases. In that way, the memory as discrimination view requires a relative similarity model to represent it accurately.

Within the model offered here, to be presented shortly, as the number of cue to target comparisons within a search increases, the relationship between distance in psychological space and similarity among items in that space changes. In the present model the scale parameter *T* is a variable equal to the size of the search set (cue-overload) as in equation 3.

$$s(Q_1,t_1) = \frac{1}{T}\exp\left(\frac{-d(Q_1,t_1)}{T}\right) \tag{3}$$

It should be noted that although the present model utilizes cue-overload as a representation of the size of the search set this is for the sake of parsimony. There may be circumstances in which search set size could vary independently of cue-overload. These circumstances would not be captured by the present model in its current form. When $T =$ 1, equation 3 it is identical to equation 2. In this way any data captured by application of variations of equation 2 (e.g. Nairne, 2005; Surprenant, Neath & Brown, 2006) is also captured through equation 3. As the size of the search set increases the value of *T* increases. This formulation of the similarity metric reduces relative similarity values when similarity is being considered within larger search sets. Figure 1 demonstrates the relationship between relative similarity and distance (equation 1) for 6 different values of *T*.

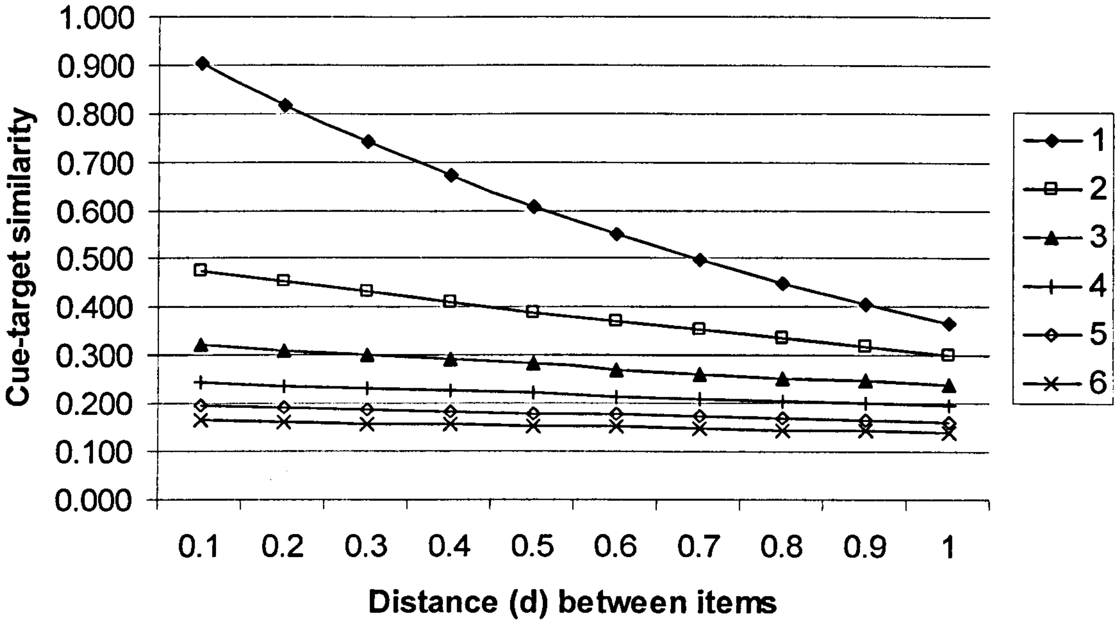


Fig. 1; Illustrates the family of distributions relating distance (*d*) to similarity (*s*) *via* equation 4. Each line represents its T value in equation 3, with the numbers 1 through 6 equalling the T value. A value of T = 1 allows equation 3 to equal equation 2.

Once similarity has been determined, a judgment must be made concerning the most appropriate candidate, and Luce's (1959) choice axiom describes the probability of correctly recalling the target given a cue, as shown in equation 4 (e.g. Nairne, 1990; Surprenant, Neath & Brown, 2006).

$$P(i \mid Q_1) = \frac{s(i, Q_1)}{\sum_{j=1}^{T} s(j \mid Q_1)} \tag{4}$$

Luce's choice rule (Equation 4) converts the similarity between cues and targets to a probability of being selected for retrieval. In the brain this is analogous to a chance of confusion (i.e. an average individual has P probability of selecting target *i* given cue *Q* and a 1-P probability of confusing it with one of the other possible memories.) In this way the more similar the cue is to other targets the greater the likelihood of the average person confusing it for the target. The numerator of equation 4 represents the similarity (*s*) between the cue (*Q*) and the item (*i*) as per equation 3. The denominator of equation 4 represents the sum of all of the similarity computations within the search, which includes the similarity between the cue and the target (the numerator) as well as the similarity between the cue and all other candidates. In that way, equation 4 describes the probability of recalling a target (*i*) given a cue (*Q*) as being equal to the similarity (*s*) of the cue (*Q*) to the target over the summed similarity of the cue to the target and all competitors.

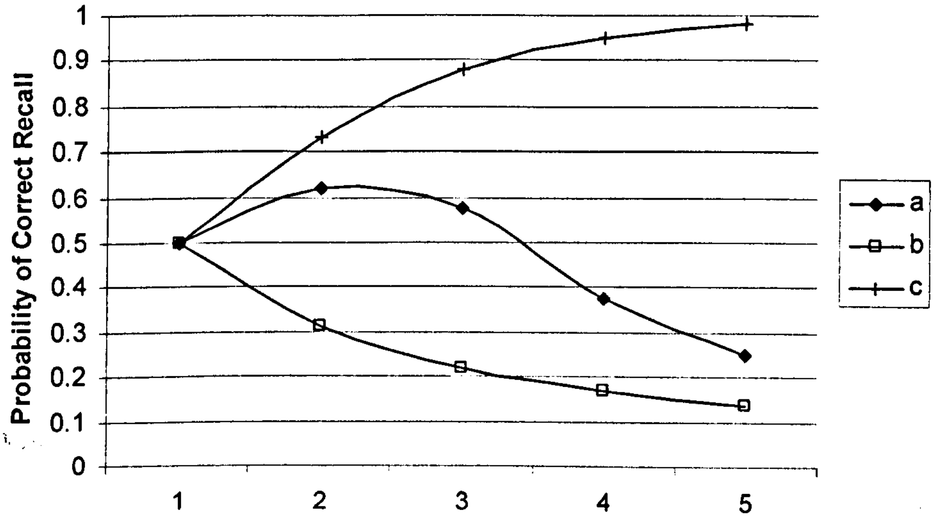


Fig. 2. Displays the predictions of the present model along increasing levels of a) encoding-retrieval match and cue-overload, b) cue-overload alone and c) encoding-retrieval match alone

Figure 2 shows the relative similarity model's predictions through use of the numbers 1 through 5 as input. The relative similarity model demonstrates the advantage of increasing encoding-retrieval match in line *a,* which then reverses and drops below the baseline value of .5 as cue-overload and encoding-retrieval match continue to increase evenly.

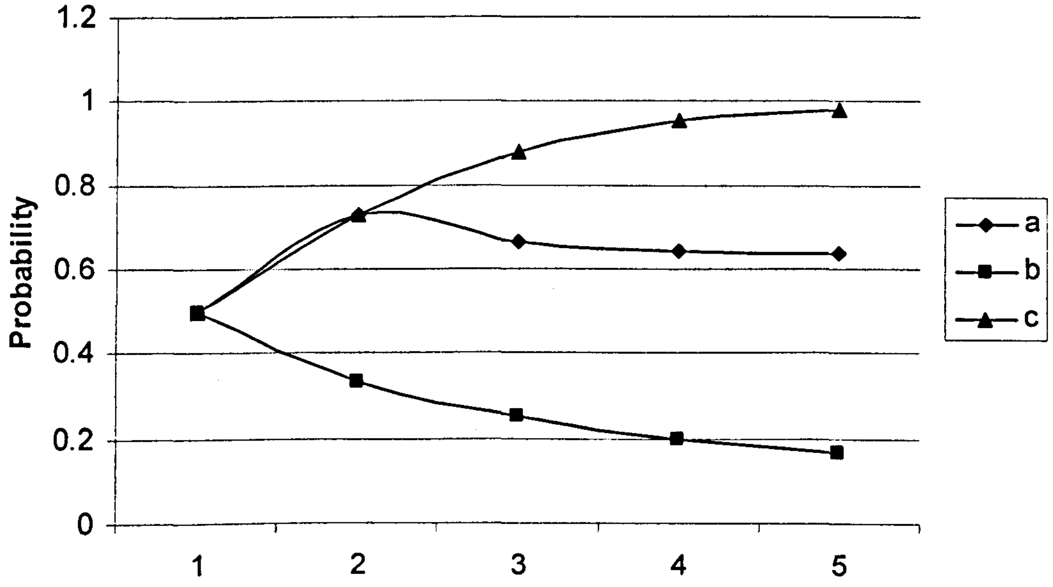


Fig. 3; Displays the predictions of SIMPLE along increasing levels of a) encoding-retrieval match and cue-overload b) cue-overload alone and c) encoding-retrieval match alone.

The predictions displayed in Figure 3 can be made using SIMPLE without any new additions, and represent a similar set of predictions to the present model. With additional free parameters it is possible for SIMPLE to match the predictions of the present model exactly. The advantage of the present model is its ability to capture reversals of encoding-retrieval match without the use of additional free parameters. Of critical interest in Figure 3 is line *a.* The memory as discrimination view investigated here suggests that if encoding-retrieval match and cue-overload effects were to increase evenly a reversal of encoding-retrieval match is expected. To capture this effect, line *a* would be expected drop below the baseline of .5 (indicative of a cue being equally capable of retrieving one of two possible targets). However, SIMPLE as illustrated in Figure 3 without further free parameters predicts that when encoding-retrieval match and cue-overload increase evenly the predictions will asymptote approaching .5.

Models have been written previously which account for some of the effects captured by the present model, albeit separately. SAM (Raaijmakers & Shiffrin, 1980) is able to capture effects of encoding-retrieval match. Anderson and colleagues in developing ACT-R (e.g. Anderson & Matessa, 1997) were able to capture the fan effect, and in so doing also account for effects of cue-overload.

ACT-R (Anderson & Matessa, 1997) accounts for the fan effect by considering the strength of association (analogous to similarity in the present model) between a cue and a target, and multiplying that value by a salience parameter (or weight). All such possible targets with an association to a cue would be activated. This is analogous to search-set inclusion in the present model. However, the sum of the weights is a fixed value. ACT-R is able to capture the fan effect due to the relationship between search set size and spread of activation. The present model considers cue-overload in each similarity calculation instead of in the amount of activation. A retrieval candidate is considered less similar to a cue as the number of potential candidates with similarities to the cue increases. In this way the present model captures both encoding-retrieval match and cue-overload through use of the similarity metric Equation 3. ACT-R does not consider relative similarity in this way. With regard to encoding-retrieval match - in ACT-R one equation captures cue-overload and another equation applies a penalty for mismatch between the time of encoding and the time of retrieval, indicative of a reduction of encoding-retrieval match. The mismatch penalty remains a free parameter in ACT-R. However, through Experimenter-controlled optimization of the mismatch penalty, ACT-R may capture data from Experiments in which encoding-retrieval match and cue-overload are orthogonally manipulated. This could be accomplished within the framework offered by Anderson & Matessa (1997) by utilizing equation 1 as a measure of mismatch to be subtracted from the ACT-R activation equation.

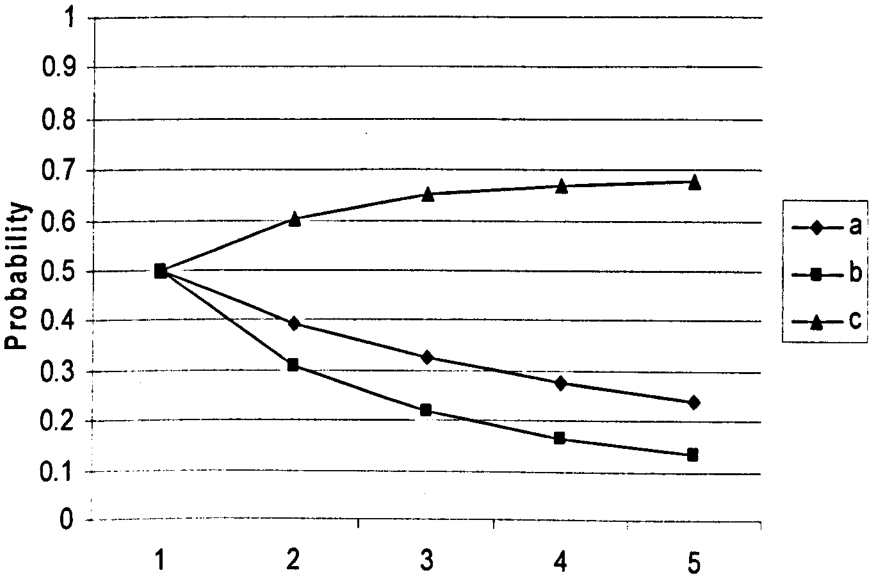


Fig. 4. Displays ACT-R probabilities across varying levels of a) cue-overload and encoding-retrieval match, b) cue-overload alone and c) encoding-retrieval match alone.

Through the spread of activation, ACT-R is able to capture effects of cue-overload as demonstrated in Figure 3. The application of a mismatch penalty allows ACT-R to capture effects of encoding-retrieval match. However, it is difficult to enable ACT-R to account for reversals of the encoding-retrieval match effect as shown with line *a* of Figure 3. Although the same set of values are entered in to the ACT-R equations as in the SIMPLE equations (Figure 3), the effect of cue-overload remains dominant in the predictions.

SAM uses Luce's choice axiom (equation 4) in a different way than does the present model (or SIMPLE). SAM focuses on the intersection between search sets by using a version of equation 4 that considers the products of cue similarities. The multiplicative relationship between cues and targets in SAM allows for encoding-retrieval match to become extremely prevalent in the generation of predictions. With that in mind, in a situation in which cue-overload effects would be minimal, SAM would be expected to generate qualitatively similar predictions to the present model. In order to capture cue-overload effects and reversals of encoding-retrieval match effects as in the present model, equation 3 could be integrated into the SAM framework along with a weight parameter that would balance the advantage naturally given to encoding-retrieval match.

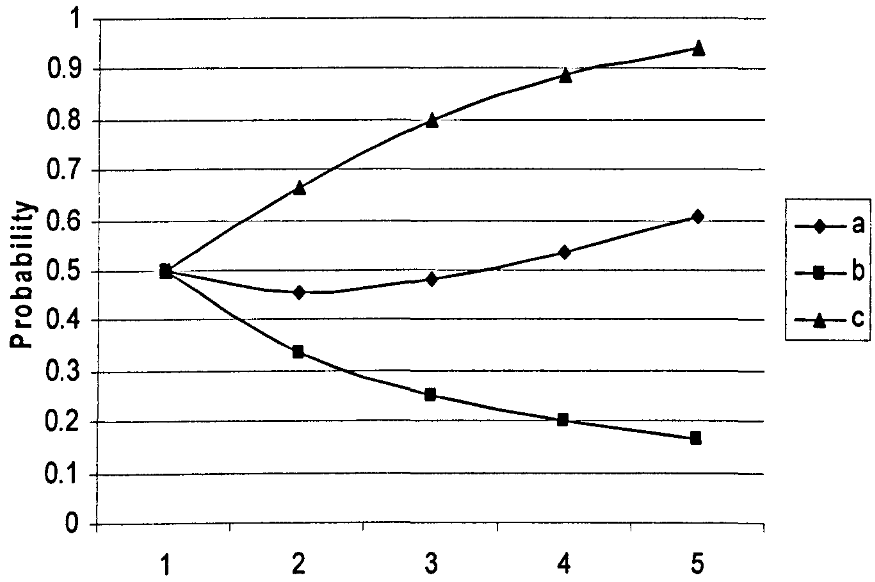


Fig. 5. Displays the predictions of SAM along increasing levels of a) cue-overload and encoding-retrieval match, b) cue-overload alone and c) encoding-retrieval match alone.

Shown in Figure 5 are the predictions of SAM utilizing the same input as those for the ACT-R (Figure 4) and SIMPLE (Figure 3) equations. It is possible to account for both encoding-retrieval match and cue-overload effects using SAM. However, due to the multiplicative relationship between matching features in SAM, the encoding-retrieval match effect is difficult to reverse. Line *a* in Figure 5 demonstrates how the effect of encoding-retrieval match continues to prevail throughout the predictions in spite of the increase of both encoding-retrieval match and cue-overload.

The example to follow compares the use of the standard version of Shepard's algorithm (equation 2, absolute similarity) and the present model (equation 3, relative similarity). A set of simulated stimuli was devised. Cueing conditions simulating the orthogonal manipulation of encoding-retrieval match and cue-overload were employed to generate predictions. If the goal of the model is to generate predictions in line with a memory as discrimination view then an increase in encoding-retrieval match without the increase in cue-overload should result in a predicted increase in probability of retrieval. However, if an increase in encoding-retrieval match is accompanied by an increase in cue-overload, the model should predict a probability of correct retrieval lower than that of an increase in encoding-retrieval match alone – simulating the possibility of a null effect or possible detrimental effect of additional cueing.

5.4: Numeric Example

The design involved four retrieval targets, each associated with three cues. Of the three cues per target – two cues were unique to their respective target while the third cue was shared by one of the other two possible targets. In this way there were ten cues and four targets as illustrated in table 1. Each cue and target was represented numerically by a vector of binary digits. The number of binaries used to represent a target was arbitrary (18 in this case) so long as all cues and targets were represented by the same number of binaries. The 18 binary digits per item were divided into three cues. Two of the three cues represented unique cues, so the binary configurations for those cues were unique. The exact configuration of the binaries was arbitrary, only that the unique binary configurations had no matching configuration in another item, and that shared binary configurations did match another. One of the three features was shared with another target, so the binary configurations for those features matched between two targets but differed to the other two targets. A single binary digit was used to represent an omnipresent environmental / Experimental context shared by all the targets.

Table 1. Cue to Target Associations

	Target 1	Target 2	Target 3	Target 4
Q1	v			
Q2	v			
Q3	v	v		
Q4		v		
Q5		v		
Q6			v	
Q7			v	
Q8			v	v
Q9				v
Q10				v
Context	v	v	v	v

Each simulated cue was composed of a vector of binary features identical to its simulated target minus a proportion of features indicative of its encoding-retrieval match condition. An encoding-retrieval match level of 1 at the time of cueing indicated the cue contained one of the three features of the target vector. An encoding-retrieval match level of 2 at the time of cueing indicated the cue held 2 of the 3 target features. An encoding-retrieval match level of 3 in this case indicates a complete cue, or 3/3 features from the encoding environment being present at the time of retrieval. Similarly an increase in cue-overload is simulated when a feature of the cue matches features of additional items. A cue-overload level of 1 indicates that the features present specify only one target. A cue-overload level of 2 indicates that a feature of the cue matches that of two items. A retrieval pass calculated the distance in psychological space (equation 1) represented by the disparity between the item vector and the cue vector. Equations 2 and 3 were then utilised as a means of transforming those values into a similarity before applying equation 4.

The results indicate two clear trends in the relationship between encoding-retrieval match and cue-overload. Table 2 shows the predicted probabilities of the retrieval model when only absolute similarity is used. The model predicts a decrease in performance with increases in cue-overload with each level of encoding-retrieval match. Likewise an increase in encoding-retrieval match, barring any change in cue-overload, leads to an increase in retrieval performance. When the model is given input values in which increases in encoding-retrieval match coincide with increases in cue-overload the model with equation 3 predicts an increase in performance each time – however, the memory as discrimination view should predict a detrimental effect instead of an increase under those conditions.

Table 2. Orthogonal predictions of encoding-retrieval match and cue-overload

Input Values	ERM1	ERM2	ERM3
CO1	0.31	0.39	0.46
CO2	0.14	0.36	0.41
CO3	0.09	0.34	0.39

Note. The probabilities of correct recall as predicted by the retrieval model inclusive of equation 2 as the similarity metric. CO represents cue-overload, with 1, 2 and 3 representing the level of cue-overload. ERM represents encoding-retrieval match, with 1, 2, and 3 representing the level of encoding-retrieval match.

Table 3 displays the orthogonal predictions of the present model utilizing the similarity metric of equation 3. When measuring the similarity of two items, equation 3 considers the number of similarity comparisons taking place simultaneously (*T*), representing cue-overload. The predictions of the relative similarity model are similar in some respects to the absolute similarity model. However, when an increase in levels of encoding-retrieval match coincides with increases in levels of cue-overload the predicted probabilities of retrieval decline as would be permitted by the memory as discrimination view. All other predictions of the model remain qualitatively identical to those generated by the use of equation 3.

Table 3. Orthogonal Predictions of encoding-retrieval match and cue-overload

Input Values	ERM1	ERM2	ERM3
CO1	0.31	0.39	0.46
CO2	0.12	0.27	0.30
CO3	0.08	0.23	0.26

Note. The probabilities of correct recall as predicted by the retrieval model inclusive of equation 3 as the similarity metric. CO represents cue-overload, with 1, 2 and 3 representing the level of cue-overload. ERM represents encoding-retrieval match, with 1, 2, and 3 representing the level of encoding-retrieval match.

5.5: *Qualitative Fit to Data*

Predictions derived from both the absolute similarity version of the model (Shepard's algorithm, equation 2) and the relative similarity version (the present model, equation 3) were fit to data derived from a paired associate learning Experiment previously reported by Fowler, Poirier, Koutmeridou & Davelaar (submitted). The design of Fowler *et al* (submitted) involves the orthogonal manipulation of encoding-retrieval match and cue-overload. The data of Fowler *et al* however is in the form of proportion of correct participant responses, and suited to be fit to the ratio model here.

This section will briefly summarize the methods of Fowler *et al* Experiment 1, which is the same Experiment 1 described in depth in chapter 3 of this thesis. Participants in Fowler *et al*, Experiment 1, were presented with words as unrelated, paired associates, having been instructed that one word would later be used as a cue and that they would be required to recall the other member of the pair. Words pairs were presented one at a time, with twelve pairs being presented per list. Words were presented in unusual fonts downloaded from an internet font database (fonts.com, 2008). Within each list, six of the twelve pairs were each presented in a unique font, while the remaining six pairs were presented in a font shared amongst all six pairs (Figure 3). After each list of twelve pairs had been presented, participants were presented with the cue words, in random order and in the same font as was originally used at the time of presentation, and were asked to type the corresponding member of the pair. The results of Fowler *et al* Experiment 1 showed a clear effect of cue-overload of font, with the shared font condition being significantly less well-remembered than the unique font condition.

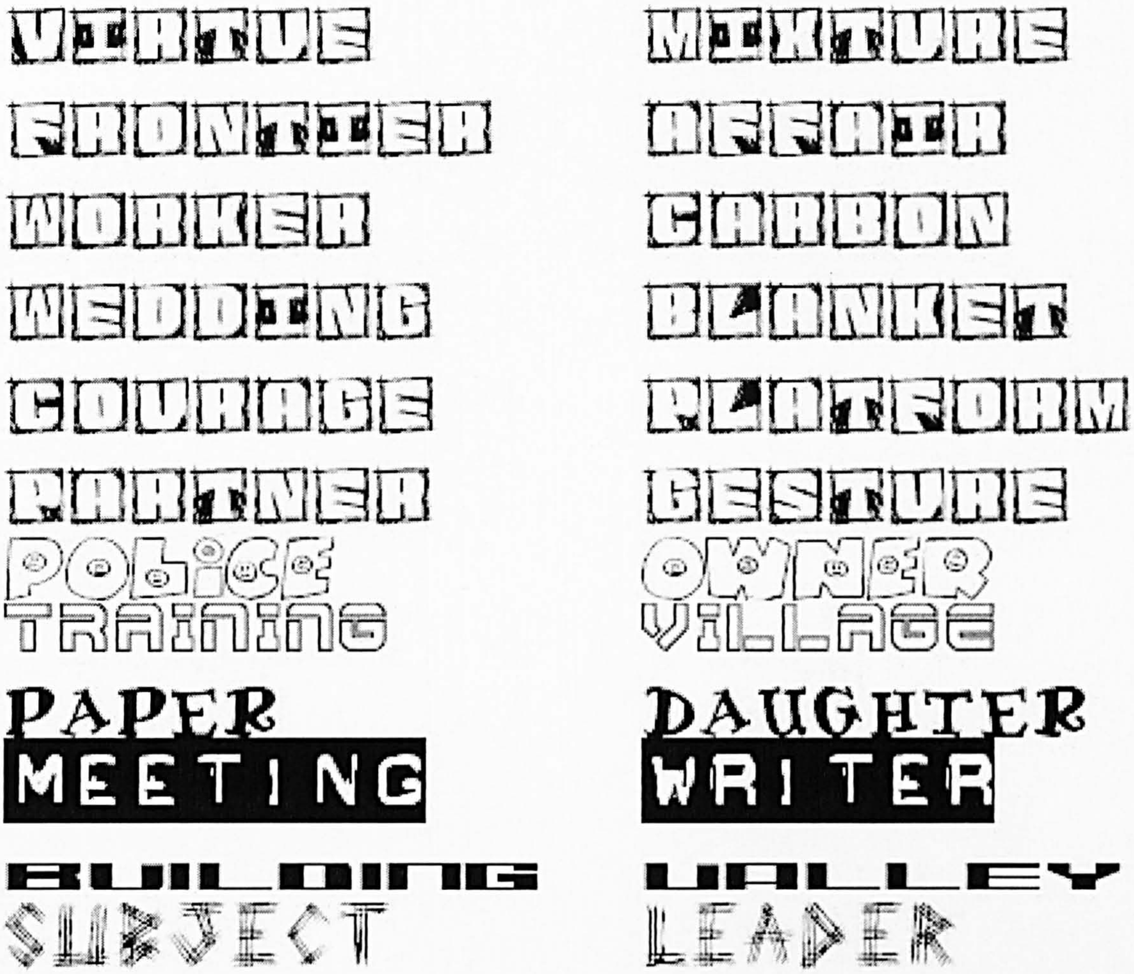


Fig. 6. An example of possible shared and unique font conditions in Fowler *et al* Experiment 1. The top 6 word pairs are presented in a shared font. The bottom 6 word pairs are presented in a unique font.

In Experiment 2 of Fowler *et al* (submitted) participants were presented with lists in conditions identical to those of Experiment 1. Half the pairs shared a font with the other six pairs were presented at study each in a unique font. However, at the time of testing the cue words were provided in either the font that was used at study, or in a novel font not yet used in the Experiment. The reinstatement of the original font constituted an increase in the level of encoding-retrieval match relative to the condition calling upon a novel font. Compared to the novel font condition, the reinstatement of the shared-font constituted both an increase in cue-overload and in encoding-retrieval match. When cues words were presented in a new font they involved a reduction of encoding-retrieval match for both conditions and a reduction in cue-overload for the shared font condition. The predictions of the memory as discrimination view are that an interaction will be present in which an effect of cue-overload will be observed in the reinstated font condition, but not in novel font condition.

Shown in Figures 7 and 8 are the fits of the ratio model utilizing equations 2 and 3 against observed data from Fowler *et al* (submitted).The general trend of the data is reflected through the use of equation 3, although the model predicts a greater effect of the reinstatement of a unique font (UR) versus the reinstatement of a shared font (SR). The model also predicts a greater effect of a reduction in encoding-retrieval match in the UN (unique/novel) condition. Of primary interest in this comparison is the capturing of the reversal of the cue-overload effect. A cue-overload effect is evident in the difference between UR and SR conditions. When both unique and shared fonts were reinstated at the time of testing, the shared font condition was less well remembered than the unique font condition. As the shared font is associated with a greater number of retrieval candidates than the unique font, this represents an effect of cue-overload. When the font used in the SR condition is not reinstated at test (SN condition) the detrimental effect of cue-overload is no longer evident.

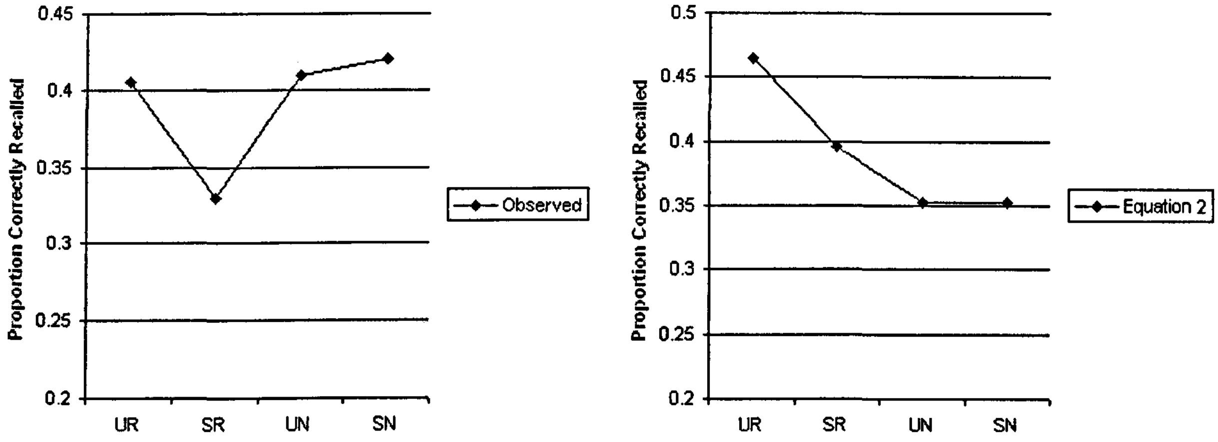


Fig. 7. represents the proportion correct as predicted by the ratio model utilizing equation 2 against observed data collected by Fowler *et al* (2010) across conditions. UN refers to the condition in which participants were shown word pairs in a unique font, with that font being reinstated at the time of testing. SR refers to a shared font that was reinstated at test. UN refers to a unique font that *not* reinstated at the time of testing. SN refers to a shared font that was *not* reinstated at the time of testing.

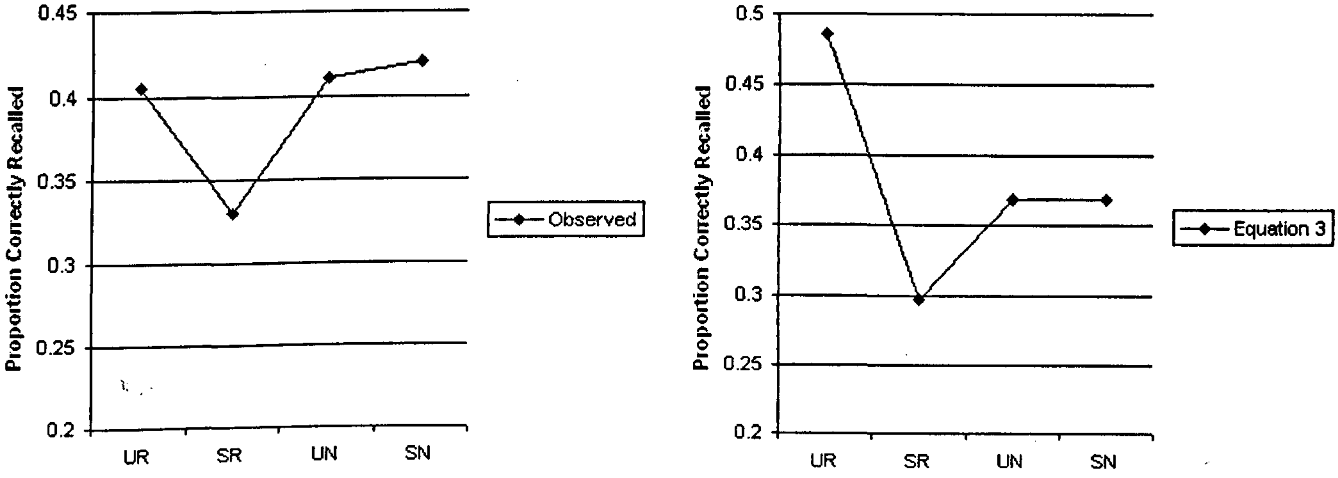


Fig. 8. represents the proportion correct as predicted by the ratio model utilizing equation 3 against observed data collected by Fowler *et al* (2010) across conditions. UN refers to the condition in which participants were shown word pairs in a unique font, with that font being reinstated at the time of testing. SR refers to a shared font that was reinstated at test. UN refers to a unique font that *not* reinstated at the time of testing. SN refers to a shared font that was *not* reinstated at the time of testing.

The data from Fowler *et al* (2010) demonstrate that increasing the level of encoding-retrieval match can be detrimental to the probability of correctly recalling the appropriate target. This is shown in the condition in which participants originally learned word pairs in a shared font, and then saw that font reinstated at the time of testing (the SR condition). When the shared font was reinstated, participants' performance was lesser than the condition in which it was not reinstated (the SN condition) in Figures 7 and 8. The reversal of encoding-retrieval match predictions (i.e. the detrimental effect of encoding-retrieval match) is captured through the use of the relative similarity model (equation 3, Figure 8). Qualitatively speaking, the trend of the predictions of the relative similarity model is similar to the trend of observed data in Figure 5. The primary, qualitative difference between the predictions of the relative similarity model and the observed values in Experiment 1 of the present investigation (Figure 8) is that the relative similarity model predicts a larger, beneficial effect of the reinstatement of the unique font. The unique, reinstated font condition (UR) in Figure 8 is relatively high.

Comparatively, the predictions of the absolute similarity model (i.e. Shepard's unmodified similarity algorithm, equation 2), do not qualitatively represent the data well. The trend of predictions from equation 2 (Figure 7) do not seem to resemble the observed values from equation 1 of the present investigation. Of particular interest to this analysis is that the use of the absolute similarity model does not permit the reversal of the encoding-retrieval match predictions found in the observed data. In the Experimental data, the non-reinstatement of context results in an increase in proportion of correct responses in the shared font condition, and no effect in the unique font condition. However, the predictions made through use of equation 2 do not capture that trend at all.

5.6: Discussion

The memory as discrimination view suggests that a retrieval cue should be diagnostically valuable in order to facilitate recall (Nairne, 2002; Poirier *et al*, in Press). In this way, an increase in encoding-retrieval match can only be seen as diagnostically valuable if it specifies a target for retrieval to the exclusion of other targets (Nairne, 2002; Poirier *et al*, in Press). The presence of cue-overload in the retrieval environment *includes*, rather than excludes potential retrieval candidates, and therefore is diagnostically non-valuable. In this study it is suggested that although a computer system may be perfectly capable of ignoring non-valuable retrieval cues and utilizing only the elements of a cue that facilitate retrieval of the appropriate target, a human participant has a probability of confusing the appropriate target with other retrieval candidates. The greater the number of potential candidates there are, the greater the probability of one of those candidates being confused with the target. The retrieval model presented in the present study (referred to as the relative similarity model) represents similarity judgements between items in memory in such a way that when multiple similarity comparisons are being made simultaneously, the similarity judgement changes. Under the relative similarity model a similarity judgement made within the context of other similarity judgments allows for a lower relative similarity value than if the judgement had been made solely between the two items. In this way, the relative similarity model regards the multiple similarity judgements as a context. This context of similarity is derived from Hunt's (2003) paper in which distinctiveness can only exist within the context of similarity, and that these similarity judgements form a context within which distinctive items may stand out. The relative similarity model does not account for distinctiveness *per se*, but creates the context of similarity between items.

The model presented as part of the present study was developed in order to explain data which existing models had been unable to adequately predict. ACT-R (e.g. Anderson & Matessa, 1997), SAM (Raaijmakers & Shiffrin, 2002) or SIMPLE (Brown, Neath & Chater, 2007) were considered as possible modes of representing the memory as discrimination view, but these models struggle to adequately demonstrate the reversal of encoding-retrieval match predictions in the presence of cue-overload. These reversals, according to a memory as discrimination view, should be represented clearly without the addition of free parameters or Experimenter-controlled constants. The relative similarity model presented in the current study allows for reversals of encoding-retrieval match predictions in the presence of cue-overload when the ratio rule (equation 4) is applied. This is exemplified in the numeric example above, in which simultaneous increases in encoding-retrieval match and cue-overload consistently result in an increase in predicted retrieval performance using the absolute similarity model (i.e. Shepard's similarity algorithm without additions). When the same values are used to generate predictions using the relative similarity model offered in the present study the simultaneous increase of encoding-retrieval match and cue-overload consistently result in a decrease in performance, reversing the encoding-retrieval match predictions. The removal of encoding-retrieval match elements that contain cue-overload (i.e. reducing encoding-retrieval match and cue-overload simultaneously) would therefore consistently result in an increase in performance.

When qualitatively fitting the predictions of the relative similarity model to data, the model represents the predictions of the memory as discrimination view. The absolute similarity model, when employed to make the same predictions does not represent the memory as discrimination view. The data presented from Fowler *et al* (submitted) generally conforms to the predictions of memory as discrimination, but not perfectly. However, the data does capture the reversal of encoding-retrieval match in the presence (and absence) of cue-overload. The absolute similarity model would suggest that with the reduction of encoding-retrieval match (the novel font condition), the proportion of correct responses would be lower than those in either of the reinstated font conditions. The memory as discrimination view predicts that with the removal of cues containing an effect of cue-overload, the proportion of correct responses would increase relative to those containing cue-overload. With that in mind, the shared font condition, when replaced with a novel font, would be expected to increase in proportion of correct responses. That prediction is captured by the relative similarity model. The Experimental data conforms to that prediction, but to a greater degree than predicted by the model. The memory as discrimination view also predicts that a reduction in encoding-retrieval match when no cue-overload is attached to the removed cues, retrieval performance is expected to decrease. This is captured by the relative similarity model in that the unique font condition, when replaced by a novel font at test, is predicted to elicit relatively fewer correct responses. The Experimental data does not seem to reflect this - however the relative similarity model comes closer to predicting the observed data than the absolute similarity model.

The relative similarity model establishes a context of similarity within which the similarity comparison between the cue and target can be made. This also sets the stage for distinctiveness effects. However, the relative similarity model does not account for distinctiveness effects in its current state. An additional parameter would need to be included in order to account for distinctiveness. However, it may be that the relative similarity model is an adequate platform from which to consider distinctiveness, as it does provide that context of similarity Hunt (2003) describes as been essential to representing distinctiveness. The literature supporting Nairne's (2002) memory as discrimination view is increasing (e.g. Fowler *et al,* submitted; Poirier *et al,* in Press). These papers suggest that under conditions in which the diagnostic value of a retrieval cue is poor (i.e. in the presence of cue-overload), a reduction in encoding-retrieval match removing those cue features containing the cue-overload effect may be beneficial. The relative similarity model captures these effects. In so doing, the model suggests that when similarity judgments are made between a cue and retrieval candidate in memory, the number of similarity judgements to be made may be a factor in determining the similarity relationship between the cue and any one of the candidates.

Chapter 6:

Conclusion

6.1: *Reflections on the aim of the thesis*

The studies included in this thesis were performed in an attempt to address essential questions pertaining to the memory as discrimination hypothesis. Investigations into the possibility of a memory being described in terms of a discrimination problem followed directly from Hunt's (2003) paper in which forgetting is described as discrimination failure and Nairne's (2002) paper in which the principle of encoding-retrieval match is described as myth. Hunt's (2003) work centred on the idea that effects of distinctiveness, only existing within the context of similarity, are evidence of a system of remembering in which a memory process must discriminate between possible candidates for retrieval and either accept or reject candidates. Within such a system those retrieval candidates which received distinctive processing could be seen as having an advantage. Nairne's (2002) paper suggested that a memory process selects a candidate for retrieval based on the similarity between the cue and the target, but also the similarity between the cue and other retrieval candidates – suggesting that the level of cue to target similarity (the encoding-retrieval match) in of itself is not enough to predict the results of the retrieval process. The point of interest in the present thesis is not the validity of encoding-retrieval match *per se*, but rather the interaction between encoding-retrieval match and cue-overload. The encoding-retrieval match principle appears to be the first port of call for experts explaining memory retrieval, and it has been hailed numerous times as an important finding in memory research (e.g. Toth & Hunt, 1999 but see Nairne, 2002). Encoding-retrieval match may or may not be a myth as described in Nairne's (2002) article, but few could deny its impact on research.

The memory as discrimination argument was originally one against encoding-retrieval match as an explanation of memory retrieval (e.g. Nairne, 2002), positing instead that a diagnostic relationship between the cue and the target was necessary to maximize retrieval performance. Studies have been able to demonstrate that encoding-retrieval match may have a beneficial, a null, or a detrimental effect on retrieval performance (i.e. Poirier *et al*, 2010; Fowler, Poirier, Koutmeridou & Davelaar, submitted), this may suggest that a causal effect of encoding-retrieval match does not exist. The present thesis set out to address questions relating to how encoding-retrieval match effects interact with cue-overload; in this way, a clearer picture of the relevance of encoding-retrieval match to retrieval may be found. Through the orthogonal manipulation of levels of encoding-retrieval match and cue-overload Experimentally the studies presented in this thesis intended to reveal interactions between these two effects as per the memory as discrimination view.

6.2: *Review of empirical work*

Investigation into the relationship between encoding-retrieval match and cue-overload required an Experimental design that features orthogonal manipulation of both. Poirier *et al* (2010) featured a task in which participants were asked to associate four consonant-vowel-consonant (CVC), nonsense-syllabic names with sets of three shapes each. Of these three shapes, two were unique to a CVC name while the remaining shape was shared between two CVCs. Participants learned these associations by repeatedly viewing the CVC names and their associated shapes in the same screen. At the time of testing participants were shown a partial set of shapes (i.e. one or two shapes), and were asked to provide the CVC that had been associated with that set of shapes. In this way both encoding-retrieval match (one versus two shapes present) and cue-overload (shared versus unique shapes present) could be manipulated orthogonally. Poirier *et al* (2010) provided evidence that in circumstances such as the tasks therein, the level of ERM was irrelevant to retrieval performance, as the pattern of results in Poirier *et al* (2010) appeared to be due almost exclusively to cue-overload in spite of the manipulation of encoding-retrieval match. The contribution of Poirier *et al* (2010) related to participants' response times. Response time for correct responses was chosen as a mode of investigation due to the fact that when responses are correct it can be assured that the participant had adequately learned the material. However, the choice of response time may have limited the contribution of encoding-retrieval match. With that in mind, the empirical work presented as part of this thesis was designed in a way that would allow for a study of the proportion of correct participant responses within a similar orthogonal manipulation of encoding-retrieval match and cue-overload.

Chapters 2 and 3 of this thesis contain the empirical studies designed to test the memory as discrimination hypothesis in participants' proportion of correct responses. The Experiments included in chapter 2 were included investigate memory as discrimination in two ways: 1) to provide a reduction of encoding-retrieval match instead of a mismatch. In previous encoding-retrieval match Experiments the reduction of encoding-retrieval match was typically done by replacing an element of the learned episode with another (i.e. changing rooms to elicit a context effect). An absent context can be seen as a pure manipulation as it would come with no extra-Experimental associations. 2) the effect of encoding-retrieval match in previous memory as discrimination Experiments has not been reliable. This is expected to occur according to the memory as discrimination view, and has been explained before (e.g. Poirier, Nairne, Morin, Zimmerman, Koutmeridou & Fowler, 2010). However, in order to strengthen the argument of a memory as discrimination view, a demonstration of results in which the effect of cue-overload interacts with a strong effect of encoding-retrieval match was necessary.

Across three Experiments in chapter 2 'spot the difference' (STD) puzzles were used as an interactive context. As the task forced participants to attend directly to them preceding the presentation of the word pairs it was predicted that the manipulation of encoding-retrieval match for these images would be likely to result in an effect. In Experiment 2 of chapter 2 a reliable effect of encoding-retrieval match is evident in the difference in proportion of correct responses between the unique/reinstated and unique/absent STD image conditions. A pure encoding-retrieval match view would predict a similar effect of reduction in match between the shared/reinstated and shared/absent STD image conditions - however, there is no difference. The diagnostic retrieval process view indicative of memory as discrimination suggests that there most likely was an effect of the reduction of encoding-retrieval match, but that this effect was counteracted by the removal of cue-overload. In the testing phase both the unique/absent and shared/absent trials are identical (i.e. only a cue word appeared on the screen). Word pairs originally presented on a shared STD image and then presented at the time of testing without that image specify a single candidate for retrieval to the same degree as the unique/absent words. This is substantiated by the data in that there is no difference between the unique/absent and shared/absent conditions.

Experiment 3 of chapter 2 allowed for a mismatch of context instead of an absent context in that during the testing phase the STD images were swapped with the contrasting condition. In chapter 2's Experiment 3 this resulted in a pattern of results similar to Experiment 2. Although encoding-retrieval match and cue-overload were both shown to have an effect as in Experiment 2, the results in Experiment 3 did not demonstrate a significant interaction between the two as they did in Experiment 2. The removal of cue-overload that allowed the an interaction in Experiment 2 by nullifying the effect of encoding-retrieval match was Experimentally different in Experiment 3. Due to the fact that the STD images were swapped with one another the shared/swapped condition not only removed an image but inherited one as well. In this regard the reduction of cue-overload was one retrieval candidate less in Experiment 3 than Experiment 2. This appears to have been enough to negate the possibility of an interaction. However, the effect of additional cue-overload in the unique/swapped condition was not enough to allow it to differ significantly from the shared/reinstated condition as expected by a strict diagnostic retrieval model (e.g. Fowler, Poirier, Davelaar & Koutmeridou, submitted). In this regard the effects of swapping or mismatching cue elements in an orthogonal manipulation of cue-overload and encoding-retrieval match is a topic for further investigation.

Chapter 3 used font type as a context for paired associates. Experiment 1 of chapter 3 identified the potential for an effect of cue-overload of font, in that half of the paired associates learned by participants were presented in the same font, whereas the remaining half of the pairs were presented each in a unique font – results showed that those pairs presented in a shared font were reliably less well remembered. With the essential effect of cue-overload of font determined, Experiments 2 and 3 of chapter 3 orthogonally manipulate both cue-overload and encoding-retrieval match. Experiment 2 of chapter 3 provides participants with paired associates in an identical manner to Experiment 1; at the time of testing, however, the fonts with which the pairs were presented was either reinstated from the learning phase or replaced with a novel font. Pairs originally presented with a unique font and then presented at test in a novel font are expected under a memory as discrimination view to exhibit a relative decline in retrieval performance as per the encoding-retrieval match principle. However, pairs originally presented in a shared font but then tested with a novel font are expected under the memory as discrimination view to exhibit a relative increase in performance that may counter-act the decrease in performance expected of the reduction of encoding-retrieval match. That is, when the cue-overload effect attached to the font is removed there is a reduction in cue-overload, as well as a reduction in encoding-retrieval match. The effects of cue-overload and encoding-retrieval match under such a circumstance would be expected to balance each other out, assuming of course the size of the effects were equal to one another.

In Experiment 2 of chapter 3 the reduction of encoding-retrieval match related to the introduction of a novel font did not result in large effect. The robust effect of cue-overload, when removed by the introduction of a novel font, resulted the proportion of correct responses for those items for which the shared font was replaced being reliably higher than when the shared font was reinstated. In this way it was demonstrated in Experiment 2 of chapter 3 that a reduction in encoding-retrieval match (i.e. the introduction of a novel font at test for word pairs originally presented in a shared font) resulted in an increase in retrieval performance.

In the testing phase of Experiment 3 of chapter 3 the font for word pairs was either reinstated or swapped with the contrasting condition. In that way items originally presented in a unique font would be presented in a shared font at test and *vice versa*). With an effect of cue-overload attached to a particular (shared) font, presenting a different word pair in that shared font should effectively transfer that cue-overload effect to the word pair. In that regard it is expected that although the unique/novel font condition of Experiment 2 in chapter 3 did not differ significantly from the unique/reinstated font condition, a reliable difference would be evident between the unique/swapped and unique/reinstated conditions of Experiment 3 due to that transfer of cue-overload indicative of the swapped condition. This prediction was supported by the data of Experiment 3 in chapter 3, and it indicated that a reduction in encoding-retrieval match can result in a reduction of performance, but as a correlation rather than a cause. The reduction in performance between the unique/reinstated and unique/swapped conditions in Experiment 3 of chapter 3 should not have been due to a reduction in encoding retrieval match – an identical reduction in match was used in Experiment 2 of chapter 3 to no effect. Instead, the reduction can be attributed to the addition of an element of the retrieval environment (the font) which carried an effect of cue-overload. An observer unaware of the manipulation of cue-overload in Experiment 3 of chapter 3 might be inclined to think that the reduction in encoding-retrieval match should explain the data. However, in line with Nairne (2002), an encoding-retrieval match explanation of the data would be an artefact of the inclusion of cue-overload.

The empirical work presented in chapters 2 and 3 delivers evidence in support of the hypothesis that the effect of increased encoding-retrieval match may be beneficial, null, or detrimental depending on the diagnostic relationship present in the retrieval environment. Across six Experiments it has been demonstrated that a cue-overload effect can be present for incidental (font) and interactive (spot the difference) contexts, and that manipulation of encoding-retrieval match pertaining to those context elements may have an effect, but only insofar as it relates to cue-overload.

It has been suggested that when 'shared' stimuli are presented in the time of learning the repeated exposure of these stimuli result in participants effectively habituating to them, removing their novelty as stimuli and reducing their ability to encode them into memory. This has been addressed in two ways in the present thesis. The first is that in Chapter 2 participants are required to spot all of the differences in a shared image, ensuring that participants must attend to the details of the image within each presentation. Second is that in the fonts series, though it may be possible to habituate to the stimuli, performance on those shared fonts would not be expected to increase in the novel and swapped conditions if the participants had not originally encoded the material successfully.

6.3: *Review of theoretical work*

The theoretical and mathematical work in chapters 4 and 5 of this thesis began simply due to the fact that no existing model was able to account for the data being produced by Experiments into the memory as discrimination hypothesis. Experiments such as Poirier *et al* (in Press) and Fowler, Poirier, Koutmeridou & Davelaar (submitted) produced data in which the effect of encoding-retrieval match had been effectively reversed by the effect of cue-overload. Application of Luce's choice rule (Luce, 1959) in which encoding-retrieval match is considered in the numerator and cue-overload in the denominator was not sufficient to account for the data. In terms of theory these reversals were exactly what was intended by Nairne (2002) in writing. However, the mathematical representation offered by Nairne (2002), and obviously intended only to introduce the possibility of further modelling, did not capture the written theory in terms of reversing encoding-retrieval match. To accomplish this goal two chapters of the present thesis were written in order to capture the diagnostic retrieval process in data – chapter 4, in which response time is considered and chapter 5, in which the proportion of correct responses is considered.

Chapter 4 begins with the essential memory as discrimination idea – that a diagnostic retrieval mechanism exists in which the best memory retrieval performance is achieved by maximizing encoding-retrieval match and minimizing cue-overload. It then analyzes response time data derived from Experiments in which encoding-retrieval match and cue-overload are orthogonally manipulated. The analyses performed in chapter 1 are made through the formulation of three linear models: one representing encoding-retrieval match, one representing cue-overload and one representing an equal contribution of encoding-retrieval match and cue-overload.

It was noted in chapter 4 that although the memory as discrimination view suggests that encoding-retrieval match is expected to have some sort of an effect on response time, that seems to be only because response time is a measure of retrieval performance. It may be that although response time and proportion of correct responses are both measures of retrieval performance, they may not both be influenced by encoding-retrieval match. Modelling and deriving predictions for the proportion of correct responses by participants is a matter of probability. An increase in encoding-retrieval match may increase that probability whereas an increase in cue-overload may reduce that probability. However, when the outcome of retrieval is certain (i.e. the responses are correct, and in the past), then it may no longer be that encoding-retrieval match need be considered.

Much like Anderson's (1974) model (which led to the fan effect and ACT-R modelling), it may be that what is of primary importance to the consideration of response time is the number of potential candidates to be rejected before the correct candidate is chosen. With that in mind, perhaps response time is only a valid indicator of cue-overload. The three regression equations presented in chapter 4 were fit to data previously reported in Poirier *et al* (2010) along with a novel Experiment utilizing the same paradigm as Poirier *et al* (2010). Of the three regression equations, the one representing cue-overload exclusively was the one that fit the data best. This is perhaps unsurprising given that of all of the Experiments performed in which encoding-retrieval match and cue-overload were orthogonally manipulated in response time measures (four Experiments thus far), none of them showed a significant effect of encoding-retrieval match independent of cue-overload. The conclusion of chapter 4 may at first appear contrary to the memory as discrimination view, but it does hold to Nairne's (2002) idea that encoding-retrieval match may be a myth. At least - when data is restricted to only correct responses in an Experiment in which both encoding-retrieval match and cue-overload are manipulated, the effect of encoding-retrieval match appears to fall short of its typical place of importance.

Chapter 5 represents encoding-retrieval match and cue-overload with regard to the proportion of correct participant responses. To contrast to chapter 4's evidence against the influence of encoding-retrieval match in response time, chapter 5 concludes that encoding-retrieval match does have an effect in terms of a proportion of correct participant responses. It is in the realm of correct responding (or chance of remembering) that encoding-retrieval match becomes virtually undeniable. After all, if cue *A* and cue *B* both belong to the original learning environment of memory trace *C*, and if presentation of *A* allows for X% chance of retrieving *C*, and presentation of *B* has an equal chance, then the combination of *A* and *B* in the retrieval environment would result in a probability of recall of $1 - X'^2$ (one minus the probability of neither cue retrieving the memory), which will always be higher. This basic mathematical proof seems to have driven much of the modelling of encoding-retrieval match, and is no less true after the conclusion of chapter 5 of this thesis. However, a proviso regarding the use of such a practice in estimating the proportion of correct responses given a particular level of encoding-retrieval match has been inserted – that those cues may not necessarily retrieve only one target. The very same simple proof that suggests that increased encoding-retrieval match must always result in an increased probability of retrieval applies to the idea that encoding-retrieval match may have a variety of effects based on cue-overload.

When taken in light of chapters 2 and 3 of this thesis, the mathematics of chapter 5 can be exemplified more clearly. Across four of the six Experiments reported in chapters 2 and 3 of this thesis encoding-retrieval match has been shown to have a beneficial, a null, or a detrimental effect on participants' proportion of correct responses depending on the level of cue-overload attached to the features of the retrieval environment. The model in chapter 5 allows for all of these possibilities. However, this is not to suggest that an effect of encoding-retrieval match is not reliable or not causally related to retrieval performance. Chapter 5 suggests that encoding-retrieval match is not monotonically related to performance as would have been suggested previously (e.g. Tulving, 1984 but see Nairne, 2002).

In chapter 3 the manipulation of encoding-retrieval match pertained to an incidental portion of the retrieval environment. That may explain the lack of effect of encoding-retrieval match there. Cue-overload effects were still generated by that manipulation, however, suggesting that the effects of encoding-retrieval match and cue-overload may pertain to portions of the memory retrieval process that activate at different stages, or otherwise relate to different facets of retrieval. This is substantiated somewhat by the lack of effect of encoding-retrieval match in response time measures such as in Poirier *et al* (2010). A strong effect of encoding-retrieval match was demonstrated in chapter 4 of this thesis, however, in a paradigm in which participants were forced to consider the context of the 'spot the difference' images. Cue-overload effects were demonstrated in that paradigm as well, and a different interaction between cue-overload end encoding-retrieval match was seen in the series presented in chapter 3 versus that in chapter 2. Further investigations into the nature of under what circumstances and to what degree encoding-retrieval match is expected to have an effect would be valuable in the refinement of the model offered by chapter 5.

6.4: *Summary and prospectus*

The memory as discrimination view is one in which two previously well-established effects (encoding-retrieval match and cue-overload) are employed to illustrate a picture of the memory retrieval process. That picture involves a constant 'give and take' between the two effects in question – in which increasing encoding-retrieval match while increasing cue-overload is supposed to result in a null effect but may shift one way or the other depending on the circumstances lending themselves to one of the two effects. Viewing the retrieval process in such a way gives the impression that the effects of encoding-retrieval match and cue-overload are consistent throughout the retrieval process and that one rules over the other circumstantially. However, when the present thesis is considered in its entirety it allows for the identification of more specific interactions between these two effects. Given that throughout the present thesis as well as in previous work such as that of Poirier *et al* (2010) cue-overload is consistently prevalent, it may be that cue-overload may be a consistent factor throughout the memory retrieval process. In contrast, encoding-retrieval match effects are at times not evident. One expect an encoding-retrieval match effect to be present in Poirier *et al* (2010), and in chapter 4 of the present series due to the fact that the features of the retrieval environment being manipulated are able to generate a cue-overload effect (i.e. they are being encoded and have an effect on retrieval). The question: 'why was there no effect of encoding-retrieval match?' in those Experiments is one for further study, but indicates perhaps that encoding-retrieval match may not be as omnipresent in the retrieval process as cue-overload.

When encoding-retrieval match is shown to have an effect, that effect is highly susceptible to levels of cue-overload. In chapter 5 the reduction of encoding-retrieval match allows for a reduction in retrieval performance only when that reduction does not coincide with a reduction in cue-overload. However, it is reasonable to predict that varying levels of cue-overload would demonstrate this effect to varying degrees. This prediction can be made due to what is ostensibly the case in everyday life. If cue-overload of context (for example) were to continue to have an effect as the number of associations between context and individual events continued to add up, then one would not be able to work at all in their office after a few years. The number of memories associated with the office, cued every time one engaged in work there, would amass to the point of being useless. Instead, it would seem to be the case that the effect of multiple memories being associated with that office becomes nullified after a point. Where that point is (with regard to a variety of stimuli) could be expected to interact differently with effects of encoding-retrieval match. Imagine a scenario in which successive cues were presented and a particular memory was the target. With each successive cue additional levels of encoding-retrieval match and cue-overload are both being added. The effects pile up, but the effect of cue-overload appears to be stronger as each cue only serves to make the participant more confused. Finally a threshold is reached in which encoding-retrieval match breaks through and the participant retrieves the correct memory. The present thesis serves as the beginnings of defining the relationship between cue-overload and encoding-retrieval match, and a variety of potential scenarios are accounted for by the mathematics of chapters 4 and 5. Chapters 2 and 3 exemplify some of these scenarios as empirical studies and are the first to demonstrate such as a proportion of correct responses. Further research is needed, however, if a model of the processes involved in the scenario described above is to be developed. The processes involved in the retrieval of memories may be diagnostic, but the mechanisms governing the relationships between memories during remembering, before memory retrieval has concluded, have yet to be defined.

When moving into the future, the patterns of results from chapters 2 and 3 should be considered. The question should be, 'why is encoding-retrieval match allowed to have an effect in the series in chapter 2, but not in the series in chapter 3?' Chapter 3 does not demonstrate a clear effect of encoding-retrieval match in that (for instance) in the unique font condition of chapter 3's Experiment 2 there is no difference between the reinstated and novel font conditions at test. The reinstatement or non-reinstatement of a unique font represents a typical manipulation of encoding-retrieval match. Cue-overload is allowed to have an effect in that same Experiment, shown by the significant difference between the unique/reinstated and the shared/reinstated font conditions, and the significant interaction. By the significant effect of cue-overload and interaction of font it can be easily suggested that participants are in some way encoding the font and being affected by it. Why, then, does it not allow for any effect of encoding-retrieval match? Likewise, why is the manipulation of encoding-retrieval match effective in the Experiments of chapter 2? The target words were derived from the same database (the Toronto noun pool) and using the same methods of counter-balancing. The same paired-associate learning task was used. The only differences between the series of Experiments in chapters 2 and 3 are: chapter 2 uses interactive context elements (spot-the-difference images) while chapter 3 uses an incidental context (font), and the cue words in chapter 2 pertained to the images themselves, whereas the cue words in chapter 3 were selected from the word pool *via* the same selection process as the target words. The models presented in chapters 4 and 5 capture manipulations of encoding-retrieval match and cue-overload when cue-overload is given greater importance than in previous models. ACT-R, SAM, and SIMPLE are able to capture effects of encoding-retrieval match and cue-overload, but additional assistance from the Experimenter (i.e. a free parameter, bias or other nudge in the right direction) would be necessary for ACT-R (e.g. Anderson & Matessa, 1997), SAM (Raaijmakers & Shiffrin, 2002) or SIMPLE (Brown, Neath & Chater, 2007) to account for the reversals of the encoding-retrieval match predictions demonstrated by the relative similarity model of chapter 5 and the trends of observed data from the Experiments reported in this thesis. Still, the relative similarity model is unable to account for variations in trends such as those evident between chapters 2 and 3. Clearly, the amount of weight given to encoding-retrieval match in chapter 3 would be different from chapter 2 in generating predictions. Hypotheses as to what factors contribute to these changes in weight, and modelling with larger data sets should be of interest for moving this line of research forward.

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