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Memory as Discrimination: Strategic Processing of Retrieval Cues

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Στον παππούκα μου

‘Ο καλός ο εργάτης και στον ήλιο και στον ίσκιο’

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Declaration

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Abstract

This thesis investigates the validity of a memory retrieval view that insists on the diagnostic relationship between retrieval cues and target memories and examines how the diagnostic value of a cue can influence the processing it receives. As a concept, the encoding-retrieval match is a widely accepted explanation of retrieval performance. According to this view, performance relates to the overlap between the retrieval information and the to-be-recalled information [see Tulving (1979, 1983) for a discussion]. The cue overload effect is another well-established phenomenon. It stipulates that retrieval performance will decrease as the number of potential targets in memory subsumed under a retrieval cue increases (Watkins & Watkins, 1975). Assuming these two factors can interact, 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, and potentially others contribute to a process of memory retrieval where diagnosticity is central (Nairne, 2002). Under such a system, retrieval is most likely to be successful when a cue specifies a target in memory to the exclusion of other potential candidates. In the second chapter, this idea is tested via three studies that use a cued-recognition paradigm. Results support the memory-as-discrimination view. However, this set of experiments brought to light another interesting phenomenon: participants appeared to prioritise the processing of the more diagnostic cues, perhaps in an effort to maximise the discrimination power of the available cue constellations. Support for this hypothesis is provided in the third chapter through a set of three experiments calling upon eye-tracking and other measures. Results from all three studies suggest that people preferentially process the more discriminative cues. How well a cue specifies a retrieval target appears to have two related effects: diagnosticity has a causal relationship with retrieval performance and it determines which cues are prioritised / processed with more emphasis.

Chapter 1:

General Introduction

1.1. Overview

The idea that memory is cue driven is at the core of the concepts explored in this thesis. A brief review of these is provided here, highlighting the importance of retrieval cues and the implications of their processing during encoding and/or retrieval. At the outset, the main goal of this thesis was to investigate the relationship between cue overload and encoding-retrieval match within the memory-as-discrimination framework. More specifically, we evaluated two alternative interpretations of the memory-as-discrimination findings (e.g. Poirier et al., 2011) that have been overlooked. The second, equally important, goal was to explore cue processing and the transformation of nominal cues into functional ones. This thesis examined the possibility that the development of functional cues may be influenced/guided by their diagnostic value, the latter affecting the amount of processing they receive as well as their later effectiveness. This introductory chapter presents the main relevant views in the field and closes with a more detailed description of the work in the present thesis, outlining the rationale and objectives of each chapter.

1.2. Memory is Cue Driven: The Role of the Retrieval Cues

Within research paradigms, recall is sometimes stimulated or not (Bilodeau, Fox and Blick, 1963) or cued or non-cued (Tulving and Pearlstone, 1966) based on the methodological design. In theory, however, retrieval is always cued (e.g. Tulving, 1976; 1983; Watkins, 1979) and one of the challenges of memory research has been to reveal and identify the cues in designs where none appear to be used (e.g. Tulving and Watkins, 1975). This means that with the appropriate manipulations, cueing effects could be observable in any experimental design. Accordingly, most recent memory models (e.g. SAM, TODAM, MINERVA, SIMPLE, FEATURE MODEL)[1] incorporate this idea [see Surprenant and Neath (2009) for a review]. Encoding specificity, encoding-retrieval match, cue overload, and memory-as-discrimination, all relate to how cues and to-be-retrieved information interact and affect performance. Encoding-retrieval match has long been considered to be a significant determinant of performance. However, the idea that memory performance depends on the diagnostic value of the retrieval cue, rather than on the encoding-retrieval match, is the backbone of this thesis. This chapter introduces each of these views to illustrate how memory-as-discrimination emerged and why the discriminative value of the cues should be considered as a critical determinant of memory performance and cue processing.

1.2.1. Encoding Specificity

Encoding specificity assumes that the target item must be encoded with some sort of reference to the retrieval cue for the latter to be effective; the original idea was that unless the cue was part of the encoded information it could not lead to successful retrieval (Tulving & Osler, 1968; Tulving & Psotka, 1971). The concept of encoding specificity emerged from efforts to investigate and explain how forgetting occurs. A brief mention of the early theories of forgetting, provided below, helps to understand the emergence of the encoding-specificity concept.

Tulving (1974) considered memory to be the result of two interacting components: a trace–the encoded information about an event that is stored – and a retrieval cue – the information present at the time of retrieval. In theory, forgetting can occur either because the trace is no longer available, or because the retrieval cue is not appropriate. Trace decay was

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[1] SAM - Search of Associative Memory (Raaijmakers & Shiffrin, 1980, 1981; Gillund & Shiffrin, 1984) is a general theory of retrieval from long-term memory that combines features of associative network models and random search models.
TODAM - Theory Of Distributed Associative Memory (Murdock, 1982, 1983) is a global memory model
MINERVA (Hintzman, 1986, 1988) is another global memory model applied mainly to category learning and recognition memory
SIMPLE – Scale Independent Memory, Perception, and LEarning (Brown, Neath, and Chater, 2002)
FEATURE MODEL (Nairne, 1988, 1990; Nairne et al., 1997; Neath, 2000; Neath & Nairne, 1995) initial focus on accounting for modality effects

amongst the most popular theories of forgetting in the 19th century (and was revived in the 1950s); it explained why a memory trace was no longer accessible postulating that, with time, the details of an event fade away rendering it unavailable (Brown, 1958). Another explanation was displacement; according to this account, the storage of new items causes the relocation of older ones in the memory system making them unavailable (Waugh & Norman, 1965). Both views suggest that when a memory trace becomes unavailable, it cannot be retrieved anymore. Feigenbaum (1961) opposed this view with his information-processing model. Within this framework, forgetting occurs due to the loss of access to the stored information in a vast network of associations. This loss of access, though, was not viewed as necessarily permanent; given the appropriate retrieval cue, retrieval could be possible. This view was expressed, as early as 1932 by McGeoch: ‘forgetting, in the sense of functional inability or loss, may result from a lack of the proper eliciting stimulus’ (pp. 365-366).

Tulving and Pearlstone (1966) set out to investigate the possibility that non-recall of familiar stimuli is due to inaccessibility, rather than unavailability of the information. They asked participants to memorize lists of categorized words and manipulated the list length (twelve, twenty-four, forty-eight words), the number of words per category (one, two, four words) and the subsequent test (free recall or cued recall). In the case of cued recall, the names of the categories were provided as cues and it was hypothesised that this would support retrieval. Performance was better in the cued-recall condition compared to free recall. Memory traces appear to still be available after the passage of time and performance relies on their accessibility. The presence of a retrieval cue (category name) facilitated access to the trace, supporting retrieval. In addition, this effect was found to be stronger as the lists lengthened but to decrease as the number of words per category increased. The latter indicates that the more a cue specifies a particular memory, the better it supports retrieval. A category name that cues many presented items is less likely to lead to successful retrieval than a category cue related to, say, one list member [this relates to the cue overload principle described later on].

Tulving and Osler (1968) attempted to provide further insight into memory retrieval and cue effectiveness by asking four questions: Can a weakly (rather than strongly) associated word lead to successful retrieval when used as a retrieval cue? Will two associated retrieval cues be better than one? Is a retrieval cue still effective if it is only presented at the time of test as opposed to being present both during learning and testing? Would a replacement, but similar, word to the one presented during learning be as effective a retrieval cue?

During learning, the participants were presented with lists of 24 to-be-remembered words (targets) studied under four conditions: either with no cue-word present, along with a weakly associated word (A), with a different weakly associated word (B) or with two weakly associate words (AB). There were also four different testing conditions: a cued-recall task with one weak associate as a cue (either A or B), a cued-recall task with two weak associates as cues (AB), and a free recall task of the targets and the cues –in cases where no cues were present during study, this condition was a standard free recall test of the targets. Each study condition was combined with each testing condition in an independent samples design. Performance was supported by the presence of a retrieval cue, even if it was a weak associate. Performance in the presence of two associates was no better, which may suggest that participants were only relying on one of them during encoding and ignored the other. Importantly, the weakly associated words were successful cues only when they were present at both learning and test. Their presence at test alone (no cue encoding condition coupled with cued-recall testing conditions) provided no advantage relatively to the free recall testing condition. The cued-recall test using a different weakly associated cue than the one presented during study [study word cue A – test word cue B or vice versa] led to worse performance than the free recall task. The pre-experimental associations between cues A & B and the target were comparable and should hence affect recall in the same way. It appears that cue effectiveness did not depend on the pre-experimental associations with the target or else the changed cue would still facilitate recall. Based on these findings, Tulving and Osler (1968) concluded that a retrieval cue must be encoded along with the target during learning for it to be effective.

Thomson & Tulving (1970) proposed that memory for events seems to depend on the use of retrieval cues that were processed along with the target at the time of encoding. This suggests that some retrieval cues lead more successfully to target retrieval than others, and that the pre-experimental cue-target associations play a minimal role. This claim was met with much scepticism especially by the supporters of the associative continuity hypothesis (Fox, Blick, & Bilodeau, 1964). According to the latter view, if there is a strong association between a cue and a target, the cue will increase the probability of successful retrieval regardless the encoding conditions. In other words, strong associates were thought to lead to successful retrieval even if they were not part of the encoding episode. Criticisms were mostly directed at Tulving and Osler’s finding that pre-experimental target associates were not effective retrieval cues unless they are processed along with the target at encoding.

Thomson and Tulving (1970) called upon Tulving and Osler’s (1968) encoding/retrieval paradigm and investigated the role of pre-experimental associates. They also tried to extend the original findings by varying the encoding conditions as well as the strength of the pre-experimental cue-target associations. During encoding, the target word was either presented alone, with a weak associate or with a strong associate. Memory performance was tested with free recall or cued recall. For cued recall, either the same associates were used as during encoding, or different associates (weak or strong). It was found that a strong associate presented at both encoding and retrieval was more effective than a weak associate that was provided at both stages, which does imply a role for pre-experimental associative strength. The presence of a strong associate only at retrieval induced higher performance compared to free recall while a weak cue at retrieval alone had no effect. However, a weak associate presented at both stages facilitated performance more than a strong associate presented only at retrieval. At the time, Thomson and Tulving concluded that pre-experimental associations are helpful indeed but only when they are provided both at encoding and retrieval: “No cue, however strongly associated with the target or related to it, can be effective unless the target is specifically encoded with respect to that cue at the time of its storage” (Thomson & Tulving, 1970, pp. 255).

The above was later incorporated into what would be referred to— and further explored as—encoding specificity: “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, pp. 369). Tulving and Thomson (1973) proposed that only encoding specificity mechanisms could explain the superiority of weak associates presented both at encoding and test, compared to strong associates presented only at test. In their paper, they briefly discuss several alternative hypotheses that accounted for the effectiveness of extra-list cues (for a detailed account see Tulving & Thomson, 1973) but they mainly focused on the most popular one, the generate-recognise hypothesis, and contrasted it to encoding specificity. The generate-recognise models (e.g. Anderson & Bower, 1974; Kintsch, 1974; Reder, Anderson & Bjork, 1974) regarded retrieval as a two stage process starting with the implicit generation of possible responses, followed by the recognition of one of them as meeting certain criteria of acceptability. This model also leads to the expectation that recall cannot possibly exceed recognition performance of the same material, as recall entails both generation and recognition.

Tulving and Thomson’s (1973) results challenged this view. They presented participants with two critical lists of 24 word pairs, where the cue was always a weak associate of the target word. After studying the lists, the participants were presented with strong extra-list associates of the target words, and they were asked to produce free association responses. The strong associates were never presented at the time of learning but only used as extra-list cues at the time of the generation test. The participants’ next task was to examine the generated associates (by going through the list of associates they produced next to each extra-list cue), and determine whether any of the studied targets were among them. Finally, participants were presented with the studied weak cues and were asked to recall the targets. A series of experiments using the same procedure (with slight variations) yielded the same results: input cues – cues that were present during encoding – were significantly more effective than any other cues. Strikingly, the actual copies of the target words that were generated via the free association task failed to be recognised in many cases. The number of target words recalled, during the last cued-recall test, exceeded the number of words that could be recognised. Tulving and Thomson (1973) point to encoding specificity as the only answer to the phenomenon: items stored as cues during encoding are more efficient in retrieving a target than a copy of the target itself, when instructions did not prepare participants for a recognition task. The encoding operations did not create a trace that was as useful for recognition as for recall, which is why the copy of the target failed to be recognised.

Tulving and Thomson’s (1973) procedure was severely criticised. Some researchers claimed that recall superiority might have been merely a by-product of the task sequence, where recognition always preceded recall (Postman, 1975; Santa & Lamwers, 1974). Participants are asked to recognise the targets after one exposure to the list items (study list). Recall, on the other hand, is tested after two exposures to the items (study list and recognition task). This additional exposure may explain why recall performance was found to be superior. Another criticism referred to the composition of the study lists. In most of the experiments studying this effect, the input pairs consisted of target words along with weakly, but semantically associated cues (Postman, 1975; Reder, Anderson & Bjork, 1974; Tulving, 1974). Successful recall of the target has been shown to be somewhat dependent on the relation between the target and the retrieval cue (e.g. Horowitz & Manelis, 1972). It could be the case that, if such a semantic relation did not exist, the results would be different.

Wiseman and Tulving (1975; 1976) successfully addressed the criticisms by amending the experimental design and the material used in a series of experiments. As a reminder, there were two critical lists containing 24 word pairs each (target and weak associate). For each target in both lists there was a strong extra-list associate word used only during the free association task. The first criticism was that during the free association task, participants were asked to elicit associates of the cues, which led to the production of the targets and increased the exposure to them. Wiseman and Tulving (1976) manipulated which strong extra-list cues were presented during the free association task, and managed to increase exposure for only half of the targets. They achieved that by presenting participants with half of the cues that were strong extra-list associates of the targets in one critical list, while the other half was strong extra-list cues for the targets in the other critical list. Thus, it was expected that each participant would only produce half the critical target words from each list, while the other half would not be elicited and their exposure would not be increased. If additional exposure is the underlying effect of superiority of recall, then participants should recall more the targets that were produced during the free association task than the targets that were not. No such result was found, as the proportion of targets recalled was identical for both generated and non-generated targets. Hence, it was concluded that recall superiority cannot be attributed to the increased exposure to the items by a previous recognition task.

The second criticism stressed the existence of the pre-existing associations between cues and targets, and how this could be responsible for the encoding specificity results. To deal with this point, Wiseman and Tulving (1976) used semantically unrelated cue-target pairs. Recall superiority over recognition was eliminated but not the recognition failure of recallable words. The latter was considered to be an extreme example of encoding specificity (Wiseman & Tulving, 1975). The concept of encoding specificity has evolved throughout the years – we will come back to that later - but in its early form it stated that, unless the cue was part of the encoded information, it cannot lead to successful retrieval (Tulving & Osler, 1968; Tulving & Psotka, 1971).

1.2.2. Encoding-Retrieval Match

The above definition of encoding-specificity appears to have suggested to many that an increase in the match of the encoding and retrieval conditions would lead to an increase in the probability of recall. The idea that memory performance relies on the reinstatement of the encoded information at the time of retrieval has a long history in psychology. For example, Hollingworth (1928) introduced the idea of “reinstatement of stimulating conditions”, which suggested that retrieval will be successful, to the extent that the [physical] stimulating conditions that were present at the time of study are reproduced at the time of test. In 1963, Melton theorised that retrieval depends on the reinstatement of the original stimuli, and Tulving and Pearlstone’s (1966) findings appeared to support this idea.

Before moving forward, we need to make clear the distinction between reinstatement and encoding specificity. While very early accounts of encoding specificity did specifically state “match” was important, this changed fairly quickly: “In its broadest form, the concept of encoding specificity holds that the cue and the trace of the to-be-remembered event must be related for the potentiality of the trace to be converted into the actuality of a remembered experience" (Tulving, 1983, pp. 224). Tulving (1983) clearly distinguished this later definition of encoding specificity from reinstatement: "The encoding specificity principle is a general assertion that remembering events always depends on the interaction between encoding and retrieval conditions, or compatibility between the engram and the cue *as encoded*; the reinstatement principle emphasizes the importance of the physical similarity between contents at study and those at retrieval." (pp. 242). Based on the former, all which is required for successful retrieval is not the reinstatement of the nominal stimuli (cues), but the compatibility of the retrieval cue with what was originally encoded. However, encoding-specificity does not make any claims about the degree of encoding-retrieval compatibility / match sufficient for retrieval, only that it must be present. It can perhaps be thought of as an 'all or nothing' rule –there is a (functional) match or there is not – and retrieval will not be successful under no match conditions.

The encoding-retrieval match hypothesis asserts that memory performance is controlled by the *extent* to which the processing at retrieval matches the processing during encoding (e.g. Tulving, 1983). This includes the proviso that an increase in overlap will lead to an increase in successful retrieval. Encoding-retrieval match is used to explain behavioural data in many research areas, such as context-dependent, mood-dependent and state-dependent memory (see Capaldi & Neath, 1995; Roediger & Guynn 1996; Smith & Vela, 2001). The assumption is that retrieval is supported by the presence of the environmental context, mood or state that existed during encoding, and if it is not present, it constitutes a reduction in match. In many contemporary studies, reinstating the physical encoding conditions is viewed as a means to stimulate the reinstatement of equivalent / similar processing. To illustrate, a brief review of a few studies relying on the encoding-retrieval match for prediction / interpretation of results is provided below.

Godden and Baddeley (1975) provided what is possibly the best known experiment involving an environmental context manipulation. In their study, members of a university's diving club were asked to learn a list of items on land, or underwater and they were subsequently tested either on land, or underwater. Recall was best when the context at test matched the one at learning (either both land, or both underwater), and the authors concluded that 'recall is better if the environment of original learning is reinstated' (pp. 330). Schab (1990) manipulated the odour (chocolate) of a small room either at study, or test or both. Even after a day's delay, participants' performance on a surprise memory test was best when the odour conditions at study and test matched. Spence, Wong, Rusan and Rastegar (2006) examined the role of colour in memory for natural scenes during encoding, and also during a cued-recognition task. Performance in a monochrome-monochrome condition was equal or superior to that in colour-monochrome and monochrome-colour conditions. Performance was best in the colour-colour condition and the authors considered those results as showing the beneficial advantage of colour, but only when there was a match: "it is not the presence of color that is important, but rather the quality of the match between the attributes of the initially presented image and the to-be-recognized partner image" (Spence et al., 2006, pp. 5).

Goodwin et al. (1969) investigated state-dependent memory in a study where alcohol or saline was administered to participants during training and/or test. Performance was best when state conditions matched during encoding and retrieval (alcohol/alcohol or saline/saline). Weingartner and Faillace (1971) produced similar results by testing two groups; chronic alcoholics and non-alcoholics. Both groups were either sober or intoxicated (1.6ml/kg of body weight) at study and at test (free recall). Both groups showed better recall when the study and test states matched than when there was a mismatch.

Bartlett and Santrock (1979) studied mood-dependent effects by altering the affective state of participants at study and at test (either happy or neutral). Once again, performance was best when the mood at test matched the mood at study. Similar results have been reported by Bower (1981). Within an encoding-retrieval match framework, these results are not surprising as they can be easily accounted for by the match between the encoding and retrieval conditions. In the course of eight experiments on prospective memory, Hannon and Daneman (2007) manipulated the characteristics of encoding, retrieval, and the match between them. They concluded that, "…all these factors have an influence on prospective memory performance, but the match between encoding and retrieval has the largest influence" (pp. 596).

An idea similar to the match, the cortical reinstatement hypothesis, is often called upon in interpreting findings within cognitive neuroscience research. This hypothesis states that: '…recollection of a recent episode occurs when a pattern of cortical activity corresponding to the episode is reinstated via activation of a hippocampally stored representation of that pattern' (Johnson & Rugg, 2007, pp. 2507). Many functional neuroimaging studies have reported findings suggesting, that the neural correlates of recollection reflect reinstatement of encoding-related activity (Nyberg et al. 2000; Persson and Nyberg 2000; Wheeler et al. 2000; Vaidya et al. 2002; Gottfried et al. 2004; Khader et al. 2005; Woodruff et al. 2005). Johnson & Rugg (2007) improved the methodology further by obtaining event-related fMRI data during both study and test allowing, thus, the direct comparison of the encoding and retrieval neural correlates within participants. Series of words were presented via two encoding tasks (words were either shown on pictures of scenes or on a blank background) that differentially engage multiple cortical regions. Memory for the words was later tested using the 'remember/know' procedure (Tulving, 1985) in order to contrast the neural activity for 'remember' and 'know' responses. The authors' logic was that subtraction would allow the identification of the neural correlates for recollection activity alone. Results showed that retrieval neuronal activity for the remembered targets was elicited in the same cortical regions as the ones during encoding of the same information. Pictures and blank screens produced activity in different regions and the content-specific associations between the neural activity at learning and at test was seen as supporting the cortical reinstatement hypothesis.

According to the encoding-retrieval match, retrieval performance is expected to be monotonically related to the degree of match determined either by the number or the appropriateness of the cues. Many changes between encoding and retrieval conditions could be interpreted as a manipulation of encoding-retrieval match, but not all of them elicit an effect. One example is Saufley, Otaka, and Bavaresco's (1985) results: college students took typical tests in a room that, either matched, or not the lecture room; results failed to support context dependent memory, as performance was not dependent on the match of the location at encoding and retrieval.

The existence of mood-dependent memory effects is generally seen as supporting the encoding-retrieval match view, but Eich (1995) reviewed the literature and suggested that other factors may also be influential. One suggested factor is the nature of target events, which may influence performance: state or mood changes may have a greater effect on internal events (conditions produced by the participants' mental processes) than external events (conditions provided by the experimenter). Another factor could be the efficacy of mood modification; the strength of mood dependence may be determined by the intensity of the manipulated moods. The mood conditions need to differ greatly, and be clearly represented by intense moods, or an effect of mood manipulation is unlikely to occur (Bower, 1992). A third suggestion is the changes of affect. Moving from one mood condition during encoding to another mood condition during retrieval may result in a change in arousal as well, which introduces another variable. A final alternative factor could be the nature of the retrieval task: free recall tasks may be more mood-dependent than old/new recognition tasks

(Eich and Metcalfe, 1989). The review by Eich and Metcalfe (1989) presents a series of factors that appear to dampen, or heighten mood/state congruence effects. In highlighting the conditions that appear necessary to produce the mood/state-based encoding-retrieval match effects, the authors draw attention to alternative interpretations of the findings they discuss.

1.2.3. Cue Overload

Several researchers suggested that 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). The cue overload principle states that ‘the efficiency of a functional retrieval cue in effecting recall of an item declines as the number of items it subsumes increases’ (Watkins & Watkins, 1975, pp. 443). The cue overload concept provides a general background to interpret a variety of phenomena, such as proactive inhibition, release from proactive inhibition, fan effects and levels of processing results (Surprenant & Neath, 2009). For the purposes of this thesis, it is important to acknowledge the role cue overload plays in the manifestation of (at least) these phenomena, which is why a brief mention to each one will be made.

In a Brown-Peterson paradigm (Peterson & Peterson, 1959), three to-be-remembered items are presented to the participants followed by a distraction task. Participants are then asked to recall the items in the order in which they were presented. Keppel and Underwood (1962) scored performance on this task by separating the trials and scoring them individually. Their results indicated that performance decreased as the number of successive trials increased (proactive inhibition). This decrease in performance across successive trials can be prevented with a change in some attribute of the to-be-remembered words, such as their category (Wickens, Dalezman, & Eggemeier, 1976). After testing memory for triads of words from the same category (e.g. flower names) for three successive trials, the experimenter can present a list with words from a different category on the fourth trial (e.g. animals).

Performance on that fourth trial will be better than it would have been if the category was kept the same across all trials. A change in category is sufficient to release the build-up of proactive inhibition, but the extent of the release varies depending on the attribute changed (see Wickens, 1970).

The registration view considers that the above findings are due to the habituation to the same category items, which results in a less efficient encoding of successive list items (Watkins & Watkins, 1975). With this in mind, the reduction of performance with the progression of trials is attributed to the position of the lists in the experiment, and is indicative of proactive inhibition. Changing the category causes dishabituation, and thus better encoding of the material, explaining the release from the proactive inhibition. According to Petrusic & Dillon (1972), the presence of proactive inhibition in recognition tests as well seems to support that it is partly due to the poorer encoding of successive trials.

An alternative explanation is that these effects are due to retrieval factors. The fact that proactive inhibition is also found in recognition tasks does not exclude this interpretation. In the recognition failure of recallable words, the cue, which is also the target, is in the context that a strong associate provides – a context that makes the target "seem different" to the encoded episode where a different, weaker associate was present. Failing to recognise words that were later recalled, for example, is evidence that recognition tasks suffer from retrieval difficulties as much as recall (Tulving& Thomson, 1973; Watkins & Tulving, 1975). Proactive inhibition in recognition tasks suggests that the functional retrieval cue may not just relate to a specific target, but also to other potential ones that share similar properties. It may well be that the functional components of a retrieval cue are affected by cue overload.

Many researchers claimed that interference is due to the difficulty in discriminating between multiple responses (e.g. Hollingworth, 1928; McGeoch, 1942; Runquist, 1975). Gardiner, Craik, and Birtwistle (1972) provided strong evidence to support a retrieval interpretation of proactive inhibition. In four successive Brown-Peterson trials, participants were presented with items from one category (e.g. sports). The first three lists included items from one sub-category (e.g. outdoor sports) and the fourth list items from another sub-category (e.g. indoor sports). All participants were asked to encode the items of the first three lists as being part of the general category, sports. One group of participants was presented with the new sub-category name along with the fourth trial. Another group received the new sub-category name only at the time of retrieval. The control group was never given any information about the different sub-category. The first two groups of participants that were somehow informed of the change showed equal release from proactive inhibition, while the control group did not. Encoding mechanisms cannot account for the above finding as, during the list presentation, all participants were given the instruction to regard items as part of the general category. Moreover, the fact that the presence of the sub-category name at encoding did not result in more release than just its presence at retrieval suggests that the release may entirely depend on the presence of an effective retrieval cue at the point of test.

Watkins and Watkins' (1975) also supported a retrieval interpretation and proposed cue overload as a suitable explanation for both the build-up and the release from proactive inhibition. According to this, the build-up occurs as more items of the same category are presented via the successive list presentations. In their view, as the trials progress, the number of potential responses to the category cue increases, thus performance decreases. A change of category immediately reduces the number of items subsumed by the category cue and thus performance increases. The extent of this release will depend on how distinct the new category is from the old one.

They tested their idea using Brown-Peterson trials (including presentation of a list of items, a distracter task to inhibit item rehearsal, and a subsequent memory recall task). Watkins and Watkins (1975) used six different word categories to create lists of three categorized words. Three lists from each category were formed resulting in 18 lists, hence 18 trials. In the course of the experiment, participants were presented with three successive lists/trials – from each of the six categories. The six categories were presented in the same order, but the list order within each category was balanced across participants. Of the 18 trials, 15 ended with the distracter task but were not followed by a memory test (untested lists). The remaining three trials were followed by the distracter task and a memory task with the category names acting as cues. Each participant was tested for one list in each position: the first list in one category, the second of a different one and the third list of another. At the end of all trials, participants were tested on all six categories with a cued-recall task.

The main focus was performance on the final cued-recall task for the untested lists. If build-up of proactive inhibition is due to cue overload alone (increase in the number of items under the category cue), then final recall should be independent of within-category presentation position. Conversely, if the build-up is due to the reduced encoding of the following same category lists, then the final recall performance should reflect that. A significant decline of within-category memory performance was found (comparing memory for the three tested lists in the first position to that in the second and third) confirming, first of all, the existence of proactive inhibition. However, in the final recall task, performance did not vary as a function of the list position, which would not be the case, if successive lists were indeed less well registered. This finding supports a cue overload explanation of the build-up and release from proactive inhibition making the insufficient registration explanation redundant.

In a second experiment, Watkins and Watkins (1975) tested the cue overload prediction that the effectiveness of the cue (category name) would decline as the number of lists per category increased. Using the same procedure as above, they also manipulated the number of lists under each category. Performance in the final recall task further supported the cue overload explanation, as it decreased when the number of lists in a category increased. The authors concluded that proactive inhibition can be explained by the use of a (category) cue that is overloaded and the release by the change to a cue that is not.

Not long before, Anderson (1974) had revealed a decline in retrieval performance as the number of items in memory under a given functional retrieval cue increased (*fan effect*). Anderson presented participants with a number of propositions (e.g. the postman is in the cottage) and introduced a novel way of cueing by using the facts about the people and locations as retrieval cues. In all, there were four manipulations of a proposition including a particular person (e.g. postman) and a location (e.g. cottage): person once-location once, person twice-location once, person once-location twice and person twice-location twice. A recognition task was later administered where participants were shown the studied proposition along with lures, and had to identify whether they were true or false. Response time (and error rates) increased as the number of items regarding a specific person or location increased. The fan effect is similar to cue overload, as it also considers the effect of multiple targets being subsumed under one functional cue. Based on cue overload, the more the cue is overloaded, the less likely it will lead to correct recall and/or more time will be needed for a response.

Craik (1979) suggested that cue overload may also explain the level of processing findings. Typical results in studies manipulating the way a person processes the information show, that the deeper the processing, the better the memory (Craik & Lockhart, 1972). Rhyming tasks are usually employed for the shallow processing condition, while semantic tasks are used for deeper processing. Craik (1979) proposed that the reason for this effect is because shallow encodings are more overloaded, and not because of the level of processing per se. Deeper levels of processing are more effective only because they lead to more unique encoding of the target, while shallow processing fails to uniquely specify one target. In other words, a meaningful sentence might provide an encoding context that is quite unique compared to that of a rhyme, the latter being shared by multiple items within (and outside of) the experiment. An implication of this is that if the level of overload of the two types of processing is equated, then the level of processing effect should disappear. Nelson & Brooks (1974) tested this hypothesis using normative data to create rhyme cues (shallow) and synonym cues (deep) with equal set sizes. Free recall data on these stimuli showed no levels of processing effect.

In the course of two experiments, Moscovitch and Craik (1976) examined the above hypothesis (deeper processing creates cues that are less overloaded) along with another one: deeper encoding questions are more memorable, hence more accessible, which is why performance is better supported. In their first study, they used three encoding questions to manipulate depth of word processing: Does it rhyme with...? Is it part of the category....? Does it fit in the sentence...?. Each encoding question was unique to a target word. They tested the accessibility hypothesis by giving participants unexpectedly a free recall or a cued-recall task. The retrieval cues used in the cued-recall task were the original encoding questions. If ease of cue accessibility is the reason why performance is boosted in the deep encoding condition, then levels of processing effect should not be present in the cued-recall task. Since all cues will be equally accessible, the advantage of the deeper encoding question should be attenuated. The levels of processing results were obtained for both free and cued-recall with the effect being actually amplified (rather than eliminated) in the latter, excluding accessibility as a possible interpretation.

In their second experiment, they manipulated depth of processing along with the type of retrieval cues (unique to the target or shared among targets). The same encoding questions as before were used, only this time they were shared among ten target words. Participants were only tested with a cued-recall task. If shallow processing leads to the creation of highly overloaded cues, then further manipulation of cue overload by sharing the same encoding question with ten targets should not make a difference. Conversely, it should greatly affect the deep processing condition, if it usually leads to minimally overloaded cues. To test this hypothesis, Moscovitch and Craik (1976) compared the cued-recall results in experiment 1 and experiment 2 examining the effect of cue overload. This comparison showed that shallow processing conditions were less affected by cue overload, than deep processing conditions. The authors argue that deeper processing enhances the effectiveness of a retrieval cue by making it less overloaded (more unique), than shallow processing does. This can be attenuated if the number of cues that receive this type of encoding increases, which will subsequently increase the load of the initially unique cue.

More recently, Sohn, Anderson, Reder and Goode (2004) hypothesised that cue overload could also be manipulated by focusing more on one item than the other. In their experiment, they used Anderson’s (1974) methodology: they presented participants with propositions including a particular person and a location keeping the number of items under a specific cue (cue overload) the same as in the original paradigm. In addition, they manipulated the instructions. They asked participants to focus on either the person or the location in a between-subjects design. The same pairs were given to both groups, the only manipulation being the instructions of how the material should be studied. In the recognition task that followed, participants had to identify the propositions that were studied versus the lures. Their results showed that the size of the fan effect was larger (there was more overload/interference) for the items that the instructions asked participants to focus upon (people or locations), than for the less focused items. These results indicate that cue overload can be manipulated via differential processing of the same material. This is a very interesting finding and its implications –as far as we know– have not been fully explored. One of the aims of this thesis is to extend these findings and explore their implications.

Cue overload appears to explain several memory phenomena - some of which were mentioned above – and to play a significant role in memory performance. It is a negative influence on memory performance, as the greater it is, the less diagnostic the cue-target relationship becomes in that an increase in cue overload increases the number of potential targets subsumed under the cue. The degree to which a cue uniquely identifies a target appears to be a determining factor of retrieval success: shared (or overloaded) cues lead to significantly lower recall performance, as they specify a target less precisely than unique cues.

1.2.4. Memory-as-Discrimination

Although cue overload is a reliable finding, it is often thought of as a less potent determinant of retrieval, with encoding-retrieval match considered to be the main influence on performance. Craik and Jacoby (1979) suggested that encoding-retrieval match and cue overload jointly determine the probability of successful retrieval: '…retrieval will be successful to the extent that retrieval processing matches encoding processes. On the other hand, the possibility of retrieving a particular event will be reduced to the extent that the target encoding is similar to other traces in the system' (pp. 158).

From a match point of view, a copy cue should be superior to other cue types, assuming that it maximises the functional match between encoding and retrieval. However, as mentioned, many studies demonstrate that a copy cue is not always the best cue (as in the recognition failure of recallable words paradigm e.g., Watkins & Tulving, 1975; Tulving and Thomson, 1973). In other paradigms, a free recall task yielded higher performance than a cued-recall task using information that was present during study (e.g. Underwood, Runquist & Schultz, 1959). Encoding-retrieval match predicts enhanced memory performance for a single target, when the degree of match between the features present at encoding and those present at retrieval increases (e.g. Tulving 1982). But the features present at retrieval may also match conditions of several *other* encoding environments, allowing for competing memory traces to be considered as possible candidates. In the latter case, where there are multiple matching instances, encoding-retrieval match predictions cannot be trusted (e.g. Hunt, 2003; Nairne, 2002). An increase in encoding-retrieval match will only be beneficial if it specifies a target more adequately, but not if it is also accompanied by an increase in cue overload (enhancing the similarity to competing targets as well) or an increase of the size of the search set. Like Nairne (2002) pointed out, even though increasing the match sometimes leads to better memory performance, this does not prove that the match is actually the causal factor. Successful retrieval performance depends on a diagnostic retrieval mechanism - the degree to which retrieval conditions uniquely specify one target to the exclusion of others (Nairne, 2001; Nairne, 2002; Surprenant & Neath, 2009). With this in mind, retrieval likelihood will be optimal under conditions where diagnosticity is highest, i.e. when cues have a distinctive relationship to the retrieval target (Nairne, 2002; Poirier et al, 2011).

Nairne (2001) and Surprenant and Neath (2009) have argued that the diagnostic value of a cue does not necessarily increase with encoding-retrieval match. According to memory-as-discrimination, the encoding-retrieval match is not causally related to memory performance. Certain match is required for a cue to be effective but the extent of that match does not necessarily predict performance. The Feature Model[2], as presented by Nairne (2001) and Surprenant & Neath (2009), provided an existence proof of this; the model demonstrates – while holding cue overload constant - that the diagnostic value of the cue is unrelated to the match; an increase in match can either increase, have no effect on, or decrease the probability of correct recall. Because of this, as it is believed by many, encoding-retrieval match may not

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[2] In the Feature Model, encoded traces, that are stored in secondary memory, consist of ordered features. The primary memory is a record of encoding and contains a fragile copy of the encoded traces. The features do not constitute a recallable item. The person has to use the processing record along with any retrieval cues to reconstruct the past event.

be monotonically related to memory performance, (Capaldi & Neath, 1995; Craik & Jacoby, 1979; Nairne, 2002).

The above view is also supported by recent experimental findings. Goh and Lu (2012) designed three experiments to examine Nairne’s (2002) claim that increasing the encoding-retrieval match could improve, have no effect or reduce performance depending on the circumstances. They used cue-target pairs with varied degrees of encoding-retrieval match and cue overload in a cued-recall task. Goh and Lu’s work demonstrated that an increase in encoding-retrieval match could improve performance, or produce no effect, but they found no evidence that increasing encoding-retrieval match could lead to a reduction in performance. Poirier et al. (2011) set out to test the counter-intuitive prediction that increasing the match could lead to a reduction of memory performance. The key argument here is that retrieval is a discrimination problem, and that the efficacy of a retrieval cue is relative to its ability to identify a single target (Nairne, 2002, 2005; Hunt, 2003). The memory-as-discrimination view, as championed by Nairne (2002), predicts that increasing the functional similarity between a cue and a target trace can lead to a reduction in performance, when the similarity between the cue and other retrieval candidates is increased as well. This is the critical prediction of the memory-as-discrimination view, as it is the most controversial from the perspective of encoding-retrieval match predictions. In a number of experiments, Poirier et al. (2011) employed a cued-recognition task (a detailed description of the task is provided in the next chapter) where people had to learn cue-target associations. Some of the cues were unique to a target, while others were shared between targets. At test, a number of the cues were presented and participants had to select a response button identifying the corresponding target as quickly as possible. The measure of performance was response time. Their findings showed that increasing encoding retrieval match by the addition of a shared retrieval cue could lead to increased response time, and thus poorer memory performance. So far, to our knowledge, these findings are the only published results other than Delosh and Nairne's findings in 1996 (see Nairne, 2005 for a detailed description) supporting this prediction.

To sum up, memory-as-discrimination reinstates cue overload as an important factor in determining the *likelihood* of correct retrieval, while it suggests that encoding-retrieval match is not predictive of memory performance (Capaldi & Neath, 1995). More importantly, the memory-as-discrimination view insists upon the importance of the diagnostic relationship between a retrieval cue and a target as the determinant of memory performance. According to this perspective, selecting the correct target depends on the cue's ability to discriminate among alternative candidates, and since the match is not relevant to how diagnostic a cue is, it is not relevant to memory performance either. It needs to be clarified here that the above does not invalidate the encoding specificity principle. On the contrary, memory-as-discrimination asserts that a certain functional similarity between a cue and a target must be present for efficient retrieval. However, manipulating the number of matching features in an effort to increase, or even maximise the cue-target similarity, is not the best way to support performance. Memory as discrimination stresses that certain match is required but what actually controls performance is the diagnostic, and not the absolute, cue-target match (Nairne, 2002).

One of the main goals of this thesis was to further investigate the relationship between cue overload and encoding-retrieval match within the memory-as-discrimination framework. In doing so, cue processing proved to be a critical determinant of performance. The amount of processing a cue receives has been shown to affect memory performance before (e.g. Sohn, Anderson, Reder, and Goode, 2004). However, some significant implications have been left untested. Further work is needed to determine the factors that guide cue processing, and to examine the extent to which cue processing is influencing retrieval. Exploring cue processing and how nominal cues are transformed into functional ones is the other main goal of this thesis. Thus, a review of the relevant literature follows.

1.3. Memory is Cue Driven: Functional Vs Nominal cues

> *'whilst part of what we perceive comes through our senses from the object before us, another part always comes out of our own mind'* – William James (1890, vol.2, pp. 103)

Tulving (1983) suggested that memory traces ('engrams') possess functional properties, rather than structural ones, and they should be described in terms of what they do, and not what they are. According to this, the material presented to the participant is known as nominal stimuli (cues or targets). What an experimenter considers as an important retrieval cue can only be thought of as a nominal retrieval cue. The component of the nominal stimulus that the participant actually encodes (and any further processing of that cue that involves knowledge or other stored information) becomes the effective cue for response elicitation, and constitutes the functional cue (Capaldi & Neath, 1995; Postman, Stark & Fraser, 1968; Underwood, 1963). The physical characteristics of an object may not change, but what is perceived differs depending on the observer's point of view. What is ultimately stored in memory does not only depend on the material and its characteristics, but also on the characteristics of the context and on the identification and processing of the stimuli. One's cognitive state provides the context within which the stimulus is interpreted (Bower, 1972b). A retrieval cue appears to be the product of a person's mental activity during encoding, but also during retrieval; depending on these activities, the same stimulus may have different cueing functions (e.g. Mathews, 1977). Tulving and Thomson (1971) referred to all the factors present at the time of learning, other than the event, that influence encoding as 'cognitive environment'. Processing the available information within a specific cognitive environment determines the nature of the functional cue, either by adding, or subtracting (or both) from the nominal cue (Neath & Surprenant, 2003).

Cue Processing

The specific processing of the information will determine the nature of the cues, but experimental manipulations can only partially affect the encoding processes, and they can never completely control them. Postman, Adams and Phillips (1955) used an early version of the encoding/retrieval paradigm to investigate encoding processes via intentional and incidental learning (a later version was used by Tulving and colleagues to explore the interactions between encoding and retrieval processes e.g. Tulving and Osler, 1968; Tulving and Thomson, 1973). Participants were shown a list of 30 adjectives and were asked to judge the frequency of occurrence of each one. In the intentional condition, they were also told their memory for the adjectives would later be tested, while in the incidental condition they were told nothing. Both groups (intentional and incidental) were divided into three testing conditions that manipulated the task difficulty, as well as the context at the time of retrieval (facilitating versus inhibitory). The first condition employed a free recall task (difficult condition), while the other two a cued-recall task (easy conditions). The manipulation of the retrieval context occurred in the cued-recall conditions; in one testing condition, the cues were extra-list words that were closely associated with the target adjective, and therefore would facilitate responses (facilitating retrieval context). In the other testing condition, the cues were remotely associated with the targets and were expected to elicit competing responses (inhibitory retrieval context). Incidental learning led to lower memory performance only in the free recall test condition. Performance of intentional and incidental learners did not differ in, either the facilitating, or the inhibitory cued-recall condition. The presence of semantically related extra-list cues (facilitating retrieval context) boosted performance, but the presence of unrelated words harmed retrieval relatively to free recall. The authors concluded that the mental activity during the learning affects subsequent ease of recall of the material irrespective of the instructions. Postman (1964) examined the literature on incidental learning and suggested that intention is not the determining factor of performance. Rather, some unobservable internal processes – triggered by the learning instructions and correlated with the following mental activity - establish the extent to which the material will be subsequently remembered. It could be the case that pre-existing associations may be responsible for the obtained results.

Based on an associative view of memory (see Anderson and Bower, 1974 for a detailed account) it is expected that a cue, A, that has acquired an association with a response, B, will become an effective retrieval cue. The association is established due to simultaneous occurrence, and its strength is determined by frequency, recency, meaningfulness, etc. (Tulving, 1983). Tulving and Pearlstone (1966) found cued-recall to be superior to free recall. The effectiveness of category names in improving memory for a list of words can be explained by the pre-existing associations between the target words and the category, which was further strengthened by their co-occurrence in the list. This explanation though fails to account for other results, such as those obtained by Underwood, Runquist and Schulz (1959). They also compared free recall of response members of a paired-associate list with paired-associate (cued) recall. This comparison was similar to the one made by Tulving and Pearlstone (1966) with one difference: the type of materials used. Underwood et al. (1959) paired nonsense syllables (cues) with adjectives (targets), thus precluding the existence of any pre-experimental associations. Unlike the previous superiority of cued recall, this time it was free recall that led to higher performance. This discrepancy between two essentially similar experiments, questioned the conditions under which a retrieval cue becomes adequately effective to increase memory performance relatively to a free recall task. In a series of experiments, Tulving and colleagues tried to determine the extent to which pre-experimental associations are responsible for the superiority of cued-recall over free recall (for a detailed account see Tulving, 1983). They concluded that those associations could not always predict a better performance during cued-recall compared to free recall. It appears that the pre-experimental associations and their strength are not sufficient to explain memory performance, and some other factor(s) comes into play.

Most experiments investigating the effect of encoding operations on cued-recall did not control for pre-existing associations between the cues and the target (e.g. Fisher and Craik, 1977; Moscovitch and Craik, 1976), which made it impossible to preclude it as a possible explanation. Mathews (1977) used word triplets to explore encoding operations in cued recall. He attempted to hold the nominal identity of the cue and target words, their pre-existing associations, and their co-occurrence during learning constant in all conditions. Thus, any observed effects could be attributed to the different mental processes occurring during the encoding of each condition. Each triplet contained two nouns that were semantically related, and members of a broader conceptual category (e.g. aluminium, cement). The third word was the name of a category and there were three encoding manipulations. In the similarity condition, the third word would indicate the conceptual category of which both noun words were members (e.g. building material). In the contrast condition, the third word would represent a category of which just one of the noun words was member (e.g. metal). In the negative encoding condition, none of the noun words were members of the category designated by the third word (e.g. beverage). During learning, the participants had to answer whether both, one or none of the nouns were related to the category. Each noun pair was presented once with each of the three category words. Half of the participants were informed before making these judgments about a subsequent memory test, in which they would be given any one of the three words and they would have to retrieve the other two. Performance did not differ between incidental and intentional learning instructions, but recall differed as a function of the encoding operations: a noun cue was most effective in retrieving the other noun under the similarity encoding condition, while it was moderately effective under the contrast condition, and not effective at all under the negative condition. This result stresses the importance of the encoding operations during presentation in determining the effectiveness of the same nouns as cues: what was compared across conditions was how well one noun cued the other but the identity of the nouns and pairs did not change across conditions. The only things that changed, in theory, were the identity of the category and the encoding operations that the instructions generated. It appears that a retrieval cue is the product of a person's mental activity during encoding, but also during retrieval and that depending on these activities the same stimulus may have different cueing functions (e.g. Mathews, 1977). 'The effectiveness of retrieval cues depends directly on how the to-be-remembered word is stored, and only indirectly on the pre-experimentally established relations between the cue and the to-be-remembered target' (Tulving, 1983, pp. 210).

Cue Selection

The processing during encoding has an impact on the effect of the individual cues during retrieval. The previous section examined cases where the type of processing was manipulated by the experimenter (incidental learning or not, focused attention to certain material, different encoding instructions). But people may also select to process some material more (or less) at their will creating effective functional cues. There was considerable interest in exploring this pre 1980s, while, to our knowledge, there was not much research relating specifically to theories of cue selection after that. This section briefly reviews the relevant literature on what could possibly guide cue selection before moving on to what may determine cue effectiveness. This chapter concludes with a suggestion of what may be a significant guiding force of both.

Underwood, Ham and Ekstrand (1962) suggested that participants in a memory task, when faced with a complex or compound stimulus, would select one of its components / features to use as an effective cue (functional cue) for the retrieval (response). According to Underwood et al., learning in a paired-associate task, where the cue has two components, can occur in different ways depending on cue selection processes. They assumed that, because of cue selection, there would be a discrepancy between the nominal and the functional cue. Some support for this claim had been previously provided by Underwood & Schulz (1960), when considering participants' verbal reports. After a paired-associate task, the participants described how they used part of the original three-letter stimulus (e.g. a single letter instead of all three letters) as a cue for the target.

If cue selection occurs, and just one part of a stimulus becomes the functional cue, what are the stimulus features that are selected in order to construct that cue?

One attribute that has been speculated to affect cue selection is meaningfulness (Solso, 1968; 1971). Sundland and Wickens (1962) investigated the learning of paired associates in a particular context (background colour), and the subsequent target recall performance with or without the context. The cues were either high frequency words, or nonsense syllables, and the targets were always words. After every five cue-target presentations each in a different background colour, anticipation trials followed, where the cue, the colour or both were presented, and participants were instructed to try to predict the target. The number of correct responses at the anticipation trials was used as indication of learning performance. Two groups were tested under each of the following learning conditions: colour (c), word (w), nonsense syllable (ns), word-colour (w+c) and nonsense syllable-colour (ns+c). After the 15th cue presentation and the regular anticipation trial, the word-colour and the nonsense syllable-colour groups received two additional trials. One group from each learning condition was tested with the colour list first, and then with the symbol (word or syllable) list, while the order was reversed for the other group. Recall performance was expressed as percentage: number of correct recalls divided by the correct responses in the last anticipation trial.

The context (background colour) was expected to facilitate learning of the less meaningful cues (nonsense syllables), but not to have an effect on learning of the highly meaningful cues (words). Moreover, recall using the associated context was expected to be better for nonsense syllables, than words. Results showed no effect of the different coloured background on the learning of either the words, or the nonsense syllables. Nevertheless, the associations between the coloured background and the cues were better for the nonsense syllables, than for the words: at the additional trials, removing the context (background colour) did not affect recall performance for the word group (97.8%), but harmed recall for the nonsense syllable group (72.8%). On the contrary, when the symbol was removed (word or nonsense syllable), performance severely deteriorated for the word group (10.8%), but not so dramatically for the nonsense syllable group (47.8%).

In a second experiment, participants were also asked to describe the stimuli they used during learning. Verbal reports indicated that very few participants used both the symbol and colour dimension of the cue. The majority used one or the other alone, or alternated between them, as if just one dimension was available. Most participants in the colour-word group used the symbols (words), while in the colour-nonsense syllable group participants used the colour alone. It seems that the highly meaningful symbols (words) overshadowed the use of the context as a potentially effective cue. In the case of less meaningful symbols though, the context resumes its value as a response cue to such an extent that it is preferred over the symbol.

Underwood, Ham and Ekstrand (1962) explored further whether the more meaningful component of a compound stimulus would become the functional cue. They presented two lists of compound cues, consisting of a verbal unit and a colour, paired with numbers as targets. In one of the lists, the verbal units were low-meaning trigrams, while in the other they were common three-letter words. Following learning of the lists (one perfect recitation), a second paired-associate list was given to the participants, including just part of each compound cue along with the targets (transfer list). Overall, there were four groups with a different combination of initial and transfer paired-associate lists (initial list + transfer list): word-colour + colour, word-colour + word, trigram-colour + colour and trigram-colour + trigram. In addition, there were two control conditions: word-colour + word-colour and trigram-colour + trigram-colour. It was expected that, if the more meaningful component of a nominal compound cue becomes the functional cue, recall performance in the transfer list would be reduced in the conditions were that component was removed. Assuming that colours are more meaningful than trigrams, it was hypothesised that the colour would be selected as the functional cue in the first list. However, in the second list it was expected that words would be selected over colours. It was therefore predicted, that if the trigrams were removed from the trigram-colour compound, there would be little effect on paired-associate performance in the transfer list. The opposite was predicted if the colour was removed from the same compound. Inversely, for the word-colour compounds, performance would be greatly affected in the transfer list by the removal of the words, but not from the removal of the colours. Results showed that, in the trigram-colour list, colour was indeed the most effective cue in eliciting correct target responses in the transfer list with the removal of trigrams having only a small effect. For the word-colour list, the presence of the words alone in the transfer lists induced more correct target responses, than the presence of the colours alone. The latter result could be due to participants' preference, in general, towards verbal material (as opposed to the colour patches used), and not entirely due to their increased meaningfulness. But the preference of colours to trigrams as functional cues was attributed to their higher meaningfulness.

Spear, Ekstrand, & Underwood (1964) replicated the above finding in a paired-associate task using compound stimuli, consisting of a trigram and a word, as cues and numbers as targets. Group W was only shown the words as cues in the transfer list, and group T was only shown the trigrams. It was expected that the more meaningful element of the compound (i.e. the word) would elicit the highest performance. Results showed that group W maintained a high level of performance throughout the transfer tests (mean of 75.75 total correct responses). Group T showed a negatively accelerated learning curve but was overall significantly below group W (mean of 52.08 total correct responses). This finding suggests that cue selection occurred, and that the most meaningful element of the compound stimulus, the words, was chosen. It seems that the more meaningful a feature is, the more probable it is that it will be selected as a functional cue.

Another attribute thought to be affecting cue selection is the degree of formal similarity among the cue features. Cohen and Musgrave (1966) created six lists of cue-target pairs with compound cues and single letters as targets. Each compound cue consisted of two nonsense syllables. In a third of the lists (mixed compound lists), one of the syllables had high formal similarity (H) with other syllables within the cue set e.g. ryg, byg, gyr, gyb, and the second syllable had low formal similarity (L) relatively to the other cue syllables e.g. tep, muz, cah, zil. In another third, the two syllables were both of high similarity (HH) and the last set of lists consisted of low similarity syllables (LL). They hypothesised that, in the mixed compound cue list (HL), the high similarity syllable would be ignored, and participants would select the relatively distinctive syllable, and associate it with the response. Results on ease of learning showed that it was easier to learn the low similarity compound lists (LL), followed by the mixed compound list (HL), and then the purely high similarity compound list (HH). In the transfer task, where only one element of the compound was shown, participants gave more correct responses to the low similarity syllables. Position of the elements also had an effect with those in the first position leading to higher accuracy. A similar result was found by Cohen & Musgrave (1964): low meaningfulness CVCs in the first position of compound cues were better learned, than when they were in the second position. Participants tend to learn initially the elements in the first position, and later on those in the second. If the second position elements are more discriminable, then they are better learned, than the ones in the first position.

Rabinowitz and Witte (1967) explored whether a single distinctive element of a multiple element stimulus would be selected to become the effective cue for response elicitation. They created a paired-associate list of non-overlapping consonant-trigram cues with numbers (ranging from one to seven) as targets. One of the trigram letters was red, while the other two were black. The position of the red letter (first, second, third) was manipulated between participants. The paired associate task was used to test learning. The learning criterion was two perfect repetitions after which a surprise transfer task followed. Participants were presented with each individual trigram letter, and were asked to assign the correct target number. Results did not show any difference in the learning rate of the lists. In the transfer task, there was a significantly higher performance (more correct responses) when the red letter was presented. It seems that participants use a single distinctive element (the red letter) of a multiple element nominal stimulus as the effective cue for responding. Examination of the letter position revealed that the first group (red letter in the first position) made significantly more correct responses to the red letter, than to the black letters, but there was no difference between the second back and the third black letter. The second group (red letter in the middle) and the third group (red letter last) did not differ in the number of correct responses across letter position. Taken together, these results suggest that participants may tend to use the initial stimulus as the functional one, and this tendency is exaggerated when it is more distinctive (see Jenkins, 1963).

Cue Effectiveness

Could cue selection be related to cue effectiveness? And what makes a cue effective in retrieving the stored information? McGeoch (1942) suggested that memory is essentially associative and cue driven. However, one cue may be associated with multiple memory targets (responses), which, in turn, may inhibit the retrieval of a given response to that cue. The inhibitory information may have been already learned (proactive interference) or acquired after the target response (retroactive interference). Information encoded during the task may activate erroneous associations and cause interference. Interference could also occur from cue confusion due to coding errors - the stimulus is encoded in such a way that it cannot be distinguished from another. Cue confusion is a significant cause of interference, when the target is not temporally or contextually separated from other items (Runquist, 1975). There is an exceptionally large body of literature on interference, which will not be reviewed here, as it is beyond the goals of this thesis. The point is to establish that cue effectiveness could be determined by the degree to which it reduces interference, and increases discrimination power. Successful memory depends on how unique or distinctive the cue-target's encoding is.

The idea that memory depends on the relative distinctiveness of the cue-target relationship is not new in the literature (Craik & Jacoby, 1979; Hunt, 2003). The cue overload principle (Watkins & Watkins, 1975) contributes to highlighting the importance of a distinct cue-target relationship; if a cue is linked to many items, and thus is encoded as part of many events (cue overload), then it is harder for that cue to elicit a single retrieval target (Earhard, 1967; Eysenck, 1979; Watkins & Watkins, 1975; Watkins, 1979; Capaldi & Neath, 1995; Hunt & Smith, 1996). A cue is distinctive to the extent that it specifies a certain target to the exclusion of others (Nairne, 2006). Distinctiveness seems to be a relational, rather than an absolute concept and an object's distinctiveness is always relative to a particular context (Schmidt, 1991; Nairne, 2006). It is not a property of the item, but is the psychological result of processing differences in the context of similarity among the items (Hunt and Worthen, 2006). According to Hunt, distinctiveness results from the processing of two types of information (Hunt & Einstein, 1981; Hunt & Elliot, 1980); relational information focuses on the similarities among discrete items within a given set contrasting it to other sets (organizational processing); item information stresses the differences among items within a set enabling the discrimination between them. Since the distinct cue-target relationship is always relative to the particular context, we need to contrast the relational and the individual cue-target information (*discriminative coding*) to establish the cue effectiveness (Einstein and Hunt, 1980). This view of distinctiveness (being a property of a cue in context) is reminiscent of, and closely related to the memory-as-discrimination view, that stresses the ability of a cue to discriminate among competing targets.

Discriminative coding is a process that can potentially attenuate interference (cue confusion and associative interference) by differentiating the cue-target relationship (Runquist, 1975). Runquist, in a series of experiments (1971; 1973b; 1974a; 1975) investigated the establishment of these discriminative cue codes in paired-associate learning using a variety of stimuli. The procedure was always the same and involved three steps. First, participants studied a paired-associate list of several stimuli. Second, all but one of the cues was presented for recall of the associated targets. Third, one of the already presented cues, or the previously missing one was shown, and participants had to indicate whether it was tested before, or not, and then retrieve the associated response. Cue confusion was measured in the cases where the missing cue was presented. If participants had coded that cue in such a way that it could not be discriminated from the tested cues, then they would report that they had seen it before. If participants correctly reported that it was missing, this would indicate the use of discriminative coding. In the 1974a study, the participants studied a list of six paired-associate consonant trigrams. Unintegrated stimuli (like the consonant trigrams used in this case) are thought to be encoded by letter location (*letter selection coding*). In this case, the overall structure of the stimulus (type and position of letters) should affect the amount of interference (Runquist, 1975). The presentation of the cues was done in three sets; in two of the sets the two trigrams had two consonants in common (high-similarity set), while in the third set the two trigrams had no common consonants (low-similarity set). The location of the common (redundant) consonants was either consistent, or varied. Recognition errors for the missing cue varied as a function of similarity; more errors were observed when the cue was from the high-similarity sets, than the low-similarity ones. In addition, common and redundant letters only had an interference effect when their position varied within the trigram. There was minimal interference when the location of the redundant, as well as the discriminative letters, was consistent. It seems that the ability to produce discriminative codes (low similarity, fixed common letter location) facilitated target identification, and it was critical to the reduction of interference.

These results were compared with those found using integrated cues (word trigrams). In this case, phonemic similarity, and not necessarily structure, is thought to affect interference to such an extent, that it could counteract the advantage of meaningful words as cues (Runquist, 1971). In a paired-associate task, Runquist (1973b) used rhyming words and consonant trigrams as cues. All the consonant trigrams shared the last two letter (consistent position), while the first one was different. The average recognition error was much higher for the rhyming words, than for the trigrams. It was concluded that the tendency to encode words as pronounceable units interfered with letter selection coding. Taken together, the above findings suggest that learners use the distinctive features of the stimulus as retrieval cues to resolve interference that could occur either due to cue confusion, or associative competition. ‘Essentially, high-similarity stimuli are made into low-similarity stimuli by selective encoding’ (Runquist, 1975, p. 148).

Runquist (1975) suggested that participants may select the more discriminative cue features as a functional cue in an effort to reduce interference. This is closely related to Sundland and Wicken’s (1962) suggestion that discriminability guides cue selection, where they considered the more meaningful cue as being more discriminative. It could be the case that the cue features that discriminate among targets the best will be selected to be the functional retrieval cues. This type of processing may be responsible for transforming nominally similar cue to functionally dissimilar ones. At this point, it needs to be clarified that not all interference reduction is due to cue discrimination. It may be the case that discriminative encoding only reduces interference at the perceptual level; it is also accepted that associative interference could still occur no matter what shared cue attributes are processed to generate distinctive codes (Runquist, 1975). The evidence provided so far may not be sufficient to clearly establish that participants use the discriminative features of the cues to differentiate targets. Regardless, here it is argued that there is sufficient data consistent with this hypothesis to allow it to be considered further in the context of memory-as-discrimination.

1.4. Summary and Overview of the Thesis

1.4.1. Summary

This thesis will investigate the interaction between (or contributions 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. Importantly, this thesis will also examine the implementation of encoding strategies, and the allocation of processing to the cues during learning and test. In doing so, different literatures are brought together ranging from cue overload to cue processing, cue effectiveness and cue selection.

1.4.2. Thesis Outline

Some of the more important questions that motivated the present work are summarised here in the form of a thesis overview. Two groups of studies are reported each of them addressing different, but related theoretical questions.

First, the reliability of the findings that support the predictions of the memory-as-discrimination view is examined. The relevant literature (e.g. Poirier et al., 2011) has not examined at least two alternative explanations that could account for the obtained results. Chapter 2 evaluates those alternative interpretations in a series of three empirical studies.

Another issue examined in the course of this thesis is the active processing of the learning material by the participants. The existing literature refers to distinctive encoding (e.g. Hunt, 2003) and the reduction of interference (e.g. Runquist, 1975) as possible guides of participants' encoding behaviour. Chapter 2 investigates this further after the discovery of a response strategy that affected memory performance. A number of questions were triggered by this discovery: Why is this particular strategy employed? What is the role of the memory cues in its formation? By the end of the chapter, a memory-as-discrimination related hypothesis is tested. Participants actively process the more diagnostic cues, whilst discounting those that would increase the discrimination problem.

A closely related issue is the development of the functional cues. Which features of the nominal cue are chosen for the composition of the functional cue? What is the process that is responsible for converting a potentially effective nominal cue into a really effective one or not? Chapter 3 explores the hypothesis that the main determinant of cue effectiveness and cue selection is their discriminative power. In three studies including an eye-tracking study, we manipulated the diagnostic value of the cues, and explored the effect on their processing, their effectiveness, and their potential selection as functional cues.

Chapter 2:

Memory as Discrimination: a Response Strategy Side Effect?

2.1. Abstract

The memory-as-discrimination view stresses that increasing the match between a retrieval cue and a target can improve, have no effect, or even decrease retention performance depending on the circumstances. According to this proposal, instead of focusing on the encoding-retrieval match, we should be focusing on the diagnostic information that a retrieval cue provides, and its ability to discriminate between competing retrieval candidates. The critical prediction of this view is that increasing the encoding-retrieval match can lead to a decrease in performance. So far, only one series of empirical findings support this prediction (e.g. Poirier et al., 2011) and additional support is required. Moreover, there are a few alternative explanations to the findings of Poirier et al. 2011 that have not been examined. Chapter 2 evaluates those alternative interpretations in a series of three empirical studies. We used a cued-recognition task where non-word targets were associated with three cues and we manipulated how discriminative each cue was; each one was either uniquely associated with a target [unique cues], or it was predictive of two targets [shared cues]. Detailed analyses revealed an unexpected response bias (response strategy): during learning, participants associated the shared cue with only one of the two possible targets, effectively treating the shared cue as if it were a unique cue for one of the targets; performance was affected accordingly (more details provided later). Because previous findings supporting the memory-as-discrimination view were based on similar tasks, this might be problematic for the proposal. Exp.2 manipulated the response strategy by calling upon a distinctive cue. Results confirmed its existence questioning the validity of previous support for the memory-as-discrimination view. In Exp.3, the task was modified to eliminate the problematic response strategy. Results provided empirical support of the memory-as-discrimination predictions. The findings are further discussed in terms of the active processing of the material during learning/study and the creation of functional cues.

Key words: Memory-as-Discrimination, Encoding-Retrieval Match, Cue Processing

2.2. Introduction

When contemplating the factors that affect successful retrieval from memory, one of the proposals most often considered is the encoding-retrieval match principle (see Goh & Lu, 2012; Poirier et al., 2011 & Nairne, 2002 for further discussion and review). The encoding-retrieval match principle states that retrieval performance is determined by the match, or overlap, that exists between the processing that occurred at encoding, and the processing at the point of retrieval (Tulving & Osler, 1968; Tulving, 1979; see Tulving, 1983 for a discussion). This principle is generally accepted and it is called upon to interpret findings in various areas of memory research. For example, Unsworth, Spillers and Brewer (2012) examined context-dependent recall and claim that “when there is a strong overlap between the contextual features present at encoding and the contextual features present at retrieval, performance is high” (Unsworth et al., 2012, pp. 1). We commonly encounter claims that ‘‘maximizing the similarity . . . between a study and a test occasion benefits retention’’ (Roediger & Guynn, 1996, pp. 204), or that ‘‘successful retrieval depends on the similarity of encoding and retrieval operations’’ (Brown & Craik, 2000, pp. 99).

Nairne (2001, 2002) challenged the idea that the encoding-retrieval match plays any causal role in performance, and insisted that the effect is merely correlational. According to this view, increasing the encoding-retrieval match tends to positively affect performance, because it is usually correlated with an increase in the cue’s power to discriminate between the target and competitors [hereafter, the memory-as-discrimination view]. Rather than an absolute match between conditions at encoding versus conditions at test, it is the diagnostic value (the discrimination power) of the conditions present at test, which is thought to matter (Nairne 2002).

The idea that memory depends on the relative distinctiveness of the cue-target relationship was introduced in the memory literature some time ago (Watkins & Watkins, 1975; Craik & Jacoby, 1979). This view insists that the power of a cue is determined by how well it discriminates among competing retrieval candidates. It relates to whether a cue uniquely predicts (is uniquely associated with) a given target, or not. For example, if a cue is linked to many items, and thus is encoded as part of many events (cue overload), then it is harder for that cue to elicit a single retrieval target (Earhard, 1967; Eysenck, 1979; Watkins, 1979; Capaldi & Neath 1995; Hunt & Smith, 1996; Hunt, 2003). Thus, as the number of items in memory associated with a cue increases, the effectiveness of that cue declines.

Despite the idea being well established in some literatures, Nairne (2006) argued that some of its implications have been overlooked. Moreover, its full impact has not been systematically tested, and the view has not taken hold in large sections of the literature (see Goh & Lu, 2012 and Poirier et al. 2011 for further discussion). The memory-as-discrimination view can be seen as related to Luce's choice rule (Luce, 1959), a simple expression of relative distinctiveness that is incorporated in a number of categorization and memory models. As such, it is included in formal models of episodic memory, such as SIMPLE (Scale Invariant Memory and Perceptual Learning; Brown, Neath, & Chater, 2002) and SAM (Search of Associative Memory, Raaijmakers & Shiffrin, 1981; Gillund & Shiffrin, 1984). This rule states that the probability, Pr, to retrieve a specific event, E1, depends on the similarity (s) between the cue, X1, and the target, E1, relative to the similarity between the cue and all potential retrieval candidates (E2 , E3, …En), as follows:

in performance, when the similarity between the cue and other retrieval candidates (denominator) is increased as well. However, Equation (1), as it is currently instantiated in memory models, does not allow an increase in the numerator to lead to a decrease in performance; the most negative consequence of increasing the encoding-retrieval match [in such a way that it maximises cue overload] is no change in performance. So, according to the Luce choice rule, as currently called upon, there are no circumstances where increasing the similarity between the cue and the target can lead to worse performance. Having this in mind, the prediction that increasing the encoding-retrieval match can lead to a decrease in performance is the critical prediction of the memory-as-discrimination view, as it is the most controversial from the perspective of encoding-retrieval match predictions. The argument is that increasing the match can sometimes lead to an increase in the denominator by increasing the functional size of the search set.

Goh and Lu (2012) designed three experiments to examine Nairne's (2002) claim that increasing the encoding-retrieval match could improve, have no effect or reduce performance depending on the circumstances. They used cue-target pairs with varied degrees of encoding-retrieval match and cue overload. Whereas Goh and Lu's work demonstrated that an increase in encoding-retrieval match could improve performance, or have no effect, they found no evidence that increasing encoding-retrieval match could lead to a reduction in performance.

Poirier et al. (2011) set out to test this counter-intuitive prediction in the context of a cued-recognition task, where response time was the main measure of retrieval efficiency. In a series of four experiments, they showed that increasing the encoding retrieval match could lead to a reduction in retrieval performance. So far, these findings are the only ones that support the critical prediction of the memory-as-discrimination view discussed above.

However, a detailed analysis of the findings and of the task called upon leads to alternative interpretations that do not support the critical prediction of the memory-as-discrimination view. This paper systematically examines these competing interpretations of the findings of Poirier et al. (2011).

Poirier et al. (2011) used the same experimental design in all their studies, which made it possible to manipulate both encoding-retrieval match, and cue overload orthogonally. Table 2.1 presents the stimuli for one of their experiments (they used different stimuli in each experiment varying from words to non-words and pictures, but the basic design was kept constant).

Table 2.1 Example of the cues and targets from Poirier et al. (2011), Exp.3.

Targets	**Cue 1 (Unique)**	**Cue 2 (Unique)**	**Cue 3 (Shared)**
Luke	Mild	Gentle	*Bright*
Anna	Elegant	Open	*Lazy*
Sophie	Chaotic	Fair	*Bright*
James	Clumsy	Kind	*Lazy*

As the table shows, for each target name there were two unique and one shared descriptors. Participants had to learn which descriptors (cues) were linked to which targets within a learning phase. Given these descriptors were used as retrieval cues in the memory test, they are referred to hereafter as unique cues, when they are associated with only one target, and as shared cues when they are associated with two of the targets. Participants were informed that the test phase would involve various combinations of cues, and that they would be required to retrieve the correct target based on the cues available. An illustration of cue combinations is provided in Figure 2.1. The figure shows buttons below the presented cues, each identifying one of the retrieval targets. Participants were asked to consider the cues, and then click on the appropriate target name as quickly as they could, without introducing mistakes due to haste.

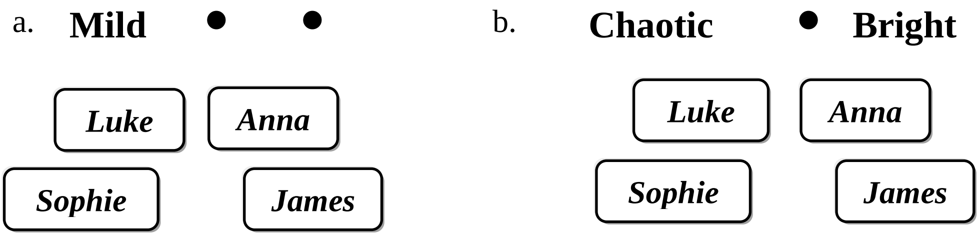


Figure 2.1 Schematic representation of testing conditions (a) one unique cue example (b) one unique and one shared cue example.

Each combination of cues at test represented a specific level of encoding-retrieval match and discrimination difficulty. If a single cue was present, then the encoding-retrieval match was less than if there were two cues present. Similarly, if the presented cue was shared with another target, the level of cue overload was increased, thereby decreasing the discrimination power of that cue. In these experiments, the critical comparisons were between the conditions where a unique cue was presented relative to the conditions where two cues were provided. Relatively to the one-unique condition, the one-unique plus one-shared condition increases the similarity between encoding and retrieval, but also reduces discriminability. In this instance, the predictions made by the encoding-retrieval match and the memory-as-discrimination view contrast each other; performance is expected to be superior in the one-unique plus one-shared condition from an encoding-retrieval match perspective, whereas it is expected to be impaired from a memory-as-discrimination angle.

In the two-unique condition, there is once again an increase in the encoding-retrieval match compared to the one-unique condition. But this time the discrimination power remains constant. However, there is the likely possibility that each of the two unique cues has a slightly different relationship to the target—varying in efficiency. If this was the case, then when one of the unique cues is presented on its own, retrieval performance could be inferior to when the other unique cue is presented on its own. In the two-unique condition though, the presence of the better learned cue along with the other unique cue should improve performance. Thus, memory-as-discrimination would predict a small increase in performance depending on how well each unique cue predicts the target on its own. As per response time, equal performance, or a slight improvement is expected in the two-unique condition compared to the one-unique, since both cues predict the same target.

Performance was measured by calling upon response time for correct trials, following a learning phase where performance was made to reach a minimum 75% correct performance criterion. This was done so that any effects could be attributed to retrieval operations, rather than to significant variations in the encoding of cue-target relationships. With just accuracy as a measure, it is not possible to distinguish between the two; when a target is associated with two cues and one of them leads to better recall accuracy, we cannot be sure this is because that cue facilitates retrieval, or because the other cue was not properly encoded with that target. This is not the case in a task where accuracy is high and the focus is on the speed of retrieval performance. In addition, it is sensible to expect an increase in discrimination difficulty to be accompanied by an increase in response time (MacLeod & Nelson, 1984).

A strict encoding-retrieval match view would predict enhanced performance in all conditions where two cues are involved relative to when only one cue is presented (one-unique-plus-one-shared and two-unique relative to one-unique). However, the Poirier et al. (2011) results supported the memory-as-discrimination predictions; when the increase in match was achieved at the expense of the discrimination power of the cue combination (one-unique plus one-shared), performance suffered. When the increase involved adding a second unique cue (two-unique condition), performance was little affected. The authors argued that the encoding-retrieval match did not predict performance; what did was the capacity of a cue to discriminate between potential retrieval candidates.

As mentioned above these findings were the first demonstration of support for the prediction that increasing the encoding-retrieval match can lead to a reduction in performance. Supporting this counterintuitive prediction is important to the memory-as-discrimination view, as it is the clearest demonstration that encoding-retrieval match cannot be relied upon to predict performance. However, the Poirier et al. (2011) results are open to an alternative interpretation that questions the validity of this central finding; this is based on a hypothesis about how participants could have completed the task in ways that were not expected / intended. In other words, the worse performance in the one-unique plus one-shared condition, relative to the one-unique condition, could be observed for reasons that are not in line with the predictions of the memory-as-discrimination view.

Alternative interpretation: cue processing order

This alternative suggests that the shared cue (S) simply delayed the processing of the more discriminative unique cue (U) [we wish to thank R. R. Hunt for this suggestion]. The hypothesis assumes that at test, participants interrupt processing as soon as they have encountered a unique cue; if cues are processed from left to right—as typical reading behaviour tends to encourage—this would have significant implications. In the critical one-unique plus one-shared condition, the shared cue’s position was randomly determined, implying that on approximately 50% of the trials it appeared first, while for the remaining 50% of the trials, the unique cue appeared first. In the latter case, a response could, in theory, be selected without further processing. However, when the shared cue appeared first, the participant had at least to categorise it as a shared cue and then move on to the next cue in order to identify the correct response. In this case, responding would take more time, than if the first cue on the left is unique and the shared cue was ignored. Assuming the above is correct, compared to a situation where a unique cue is presented either on its own, or with another unique cue, on average the one-unique plus one-shared condition would be slower, as the results showed. Crucially however, this would not be because of the more difficult discrimination problem introduced by the one-shared cue; the slower response time would be attributable to the delay introduced by the one-shared cue for those trials where it slowed the processing of the more useful one-unique cue.

The first study described below reports a detailed analysis of responding, where the above suggestion is examined. To summarize, assuming that the cue-target match is the most important factor in retrieval, an improvement in performance would be expected when going from a single cue to a situation that re-instates two of the three original cues. However, if the discrimination problem posed to the memory system is the determinant of performance, then one would expect performance to drop in the case of the one-unique plus one-shared condition, and to remain essentially the same or improve when two unique cues are presented. For this interpretation to hold, the pattern of results must be shown to not depend on the processing order of the presented cues. To test this, we called upon an experimental task that had the same characteristics as the one used in Poirier et al.’s Exp.1.

2.3. Experiment 1

2.3.1. Method

2.3.1.1. Participants

Twenty-seven participants (15 Male, 12 Female), with a mean age of 25 (SD=5.1), completed the task. This sample is sufficient to provide enough power (.95) to detect small differences. They responded to advertisements posted through City University London systems and were rewarded with £5 for their participation.

2.3.1.2. Design and Materials

Presentation of stimuli, timing and response recording were done through a program developed with Macromedia Authorware. Four consonant-vowel-consonant trigrams (CVCs) were used as targets, and four sets of geometric shapes used as cues. Participants had to learn which cues predicted which targets. Some of the shapes were shared between two targets, whereas others were uniquely predicting one of them (see Figure 2.2a). The shapes were used as retrieval cues in the memory test and they will be referred to here as unique cues, when they were part of only one target and as shared cues, when they were predictive of two targets. We used relatively unfamiliar cues and targets to control for prior experience with the stimuli. Pre-testing established that task difficulty would be too high if more than four targets and their associated cues had to be learned simultaneously. Figure 2.2 provides the complete set of stimuli, as well as an example of how they were presented during learning (see Figure 2.2b). The size of all shape pictures (171cm x 140cm) and of all trigrams (100x100) was kept constant throughout the experiment. The position of the cues on the screen was randomly determined on each trial during learning and testing. In addition, the combination of shapes between them, as well as which shapes were shared/unique and their combination with a specific target, was randomly determined and differed across participants.

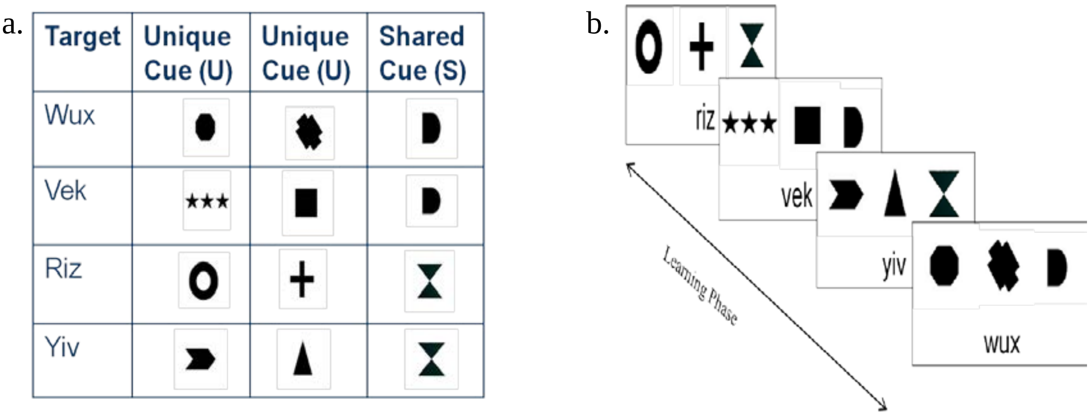


Figure 2.2 a. Cue-target sets; b. Stimuli presentation during learning

2.3.1.3. Procedure

Participants were individually tested, in a sound-attenuated booth; a session lasted approximately 20 minutes. The study consisted of a learning, training and test phase. During the learning phase, each target was presented on screen along with its three cues for 10 sec; there was a 0.5sec interval between each target and cue set. The presentation involved a random selection without replacement of one of the target-cue sets, until all four had been presented twice. The encoding of cues and target involved all three cues being simultaneously presented, along with the to-be-retrieved target. Participants knew that in the test phase, various combinations of cues would be presented, and that they would be required to retrieve the correct target.

The training phase that followed was identical to the actual test phase that came later on. Participants were presented with one or two of the cues (a partial cue), and were asked to select the corresponding target by clicking as quickly as possible on a response button (see Figure 2.3). The response buttons, each identifying one of the retrieval targets, were randomly placed across participants. The cursor was automatically re-positioned at the start of each trial at co-ordinates that made it equidistant from all response buttons. The cues that were not presented were replaced by a small filled square.

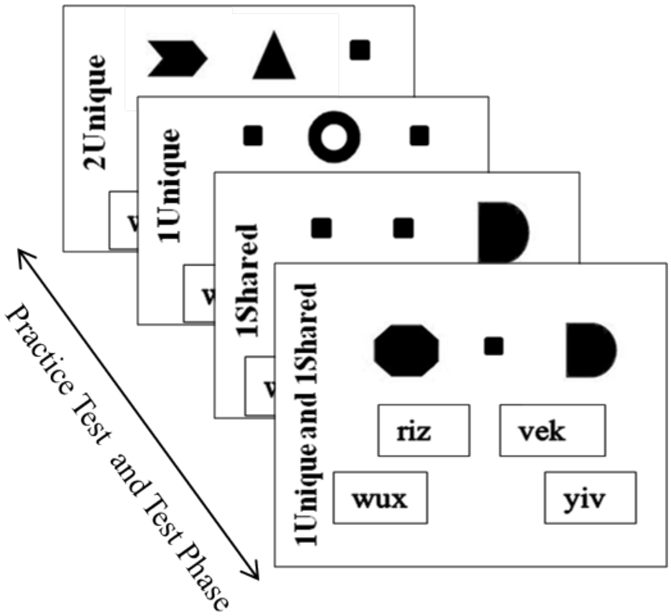


Figure 2.3 Cued-recognition trials testing, starting at the back, two-unique, one-unique, one-shared and one-unique plus one-shared conditions. The participant has to click on the button identifying the correct CVC target.

In one block there were 96 trials testing the following conditions 24 times (six for each target): one-shared, one-unique, one-unique plus one-shared and two-unique. The participants were forewarned that sometimes, more than one response would be correct [when one-shared cue was presented on its own]; they were told that either of the two responses was acceptable. As there are two possible answers in response to this cueing condition, it is difficult to compare performance in this case to that in the other cueing conditions. We, nevertheless, included a one-shared condition in the testing to ensure that participants did not ignore the shared cue. After completing the first block, the participants were shown the targets and cues simultaneously again, as a reminder, and then had to complete a further block. This was repeated, until they reached a 75% correct performance criterion for each condition. Once they had reached the performance criterion, they moved on to the test phase. This training phase was necessary to ensure adequate levels of performance and sufficient encoding, but as far as the participants were concerned this was a proper testing phase.

During the final test phase four blocks were administered resulting in a total of 384 trials (96 per testing condition). The number of correct and incorrect responses was recorded, as well as median response time for correct trials (in milliseconds-ms).

2.3.2. Results and Discussion

Memory-as-discrimination analyses

All participants exceeded the 75% accuracy criterion in each condition (see Table 2.2). Accuracy performance appears to be better in the two-unique condition, than the one-unique condition and the one-unique plus one-shared condition. There seems to be no difference between one-unique plus one-shared and one-unique condition. The highest performance was observed in the one-shared condition, but this is not surprising, as there were two possible correct responses. As for response time, only correct trials were considered. We averaged response times across participants after we had identified the median response time per condition for each participant. The one-unique-plus-one-shared condition appears to be slower than the other two. The fastest response times were observed in the one-unique condition, followed by the two-unique condition.

Table 2.2 Accuracy and response time (RT) results based on cue type

	Cue Type Mean (SD)			
	one-shared	one-unique	one-unique plus one-shared	two-unique
Accuracy	.97 (.01)	.86 (.03)	.88 (.02)	.94 (.02)
RT (sec)	1.61 (.10)	1.43 (.06)	1.99 (.08)	1.60 (.08)

The one-shared condition was not included in the analyses as there were two correct responses available. A repeated measures ANOVA on accuracy revealed a significant main effect of cue type: F (2, 52) = 11.26, p<.001, eta square = .30; Pairwise comparison tests (Tukey) revealed that two-unique (M=.94, SD=.025) was significantly more accurate (p<.001), than both one-unique plus one-shared (M=.88, SD =.02), and one-unique (M=.86, SD =.03). Accuracy for the one-unique-plus-one-shared condition did not differ from the accuracy for the one-unique condition.

A repeated measures ANOVA on response time showed a significant main effect of cue type: F (2, 52) =27.5, p<.001, eta square = .51. Pairwise comparison tests (Tukey) revealed that one-unique plus one-shared (M=1.98, SD =.08) was significantly slower (p<.001), than both two-unique (M=1.60, SD =.08), and one-unique (M=1.43, SD =.06). One-unique was marginally faster than two-unique (p=.05).

The above findings are generally in line with Poirier et al. (2011), and the memory-as-discrimination predictions; participants were significantly more accurate in the two-unique condition compared to the one-unique, and to the one-unique plus one-shared condition. In addition, they were significantly slower in the one-unique plus one-shared condition than in the other two. As discussed in the introduction though, the above results could have also been obtained by differential processing of the cues based on their presentation position on screen. To rule out this possibility, we performed additional analyses that took into account the presentation position of the cues from left to right.

Cue processing order analyses

This alternative interpretation relies on two assumptions: 1) the cues are mostly processed from left to right—the natural direction of reading—and 2) processing is interrupted when a unique cue is encountered. Under these assumptions, when the shared cue appears first, the participant must, at least, identify it before moving on to the next cue. In this case, responding would take more time than if the first cue on the left was unique and the shared cue was ignored. In order to examine whether there is an effect of cue processing order, for each participant, the one-unique plus one-shared trials were split into two groups, depending on the position of the shared cue. On average, there were 48 trials where the shared cue appeared in the leftmost position relative to the unique cue, and 48 trials where the reverse was true. A paired samples T-Test showed no significant difference in response time between these trial types: t (26) =.312, p>.05; when the shared cue was left the mean RT was 1.79 (SD=.38) and when the unique cue was left the mean RT was 1.77 (SD=.35).

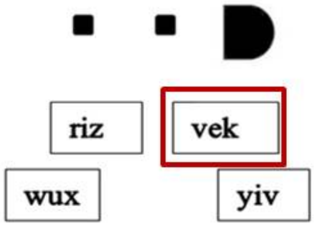
The suggestion that the order in which the cues were processed might have influenced the response time in that condition was not supported. However, our systematic examination of the raw data revealed an unexpected finding: the participants were strategically processing the shared cues (just not as it was thought above), which led to a response bias. When presented with the one-shared condition, participants preferentially selected ***one*** of the two possible correct targets (*response selection bias*). For example, if the shared cue was a half-moon shape and both Vek and Wux were correct responses, many participants appeared to select one of these responses systematically (i.e. over 80% of the time). This suggested that both correct targets would not be brought to mind by the shared cue as readily. If this was the case, then another alternative to the memory-as-discrimination interpretation of the findings needed to be considered.

Strategic processing of shared cues

This second alternative view of the Poirier et al. (2011) findings suggests that the actual processing of the shared cue was not as intended. Under this hypothesis, when participants are presented with a shared cue during learning, they elect to associate it preferentially with one of the two targets that the cue predicts. For example, the first time the shared cue is encountered, it is in effect a unique cue, as it appears with a single target; it might be that participants choose to view the shared cue as predicting this target, while supressing (not ignoring completely however) its relationship to a further target. This would be tantamount to treating the shared cue as a (somewhat) unique cue – a strategy that might reduce the resources needed to encode the cue-target relationship.

What would be the consequences of such a strategic processing? Consider the following example (see Figure 2.4 below); assume that a given participant chooses to bind a shared cue to target A, and to inhibit or supress its equivalent relationship to target B. When presented with a one-unique plus one-shared cue that predicts target A, response selection would proceed swiftly and efficiently. However, when presented with a one-unique plus one-shared cue that predicts target B, conflicting responses would be elicited; the one-unique cue predicts target B, but for this participant the one-shared cue mostly predicts target A. The correct response could presumably be selected based on the one-unique cue, but not without some slowing of the response selection process.

a) Test phase presenting a shared cue between target A (Vek) and target B (Wux):



b) Test of target A (Vek):

c) Test of Target B (Wux):

Figure 2.4 Illustration of the response selection bias: (a) when cued with the half-moon, the participant overwhelmingly responds Vek neglecting the other possibility (Wux). (b) Response times for the one-unique plus one-shared condition that cues target Vek will be faster, than (c) the same condition that cues target Wux, because of the differential association strength between the shared cue and the two targets.

In this example, in the one-shared condition with the half-moon the participant mostly selected Vek as the correct response ignoring Wux (see Figure 2.4a). This stronger association of the half-moon with Vek could significantly increase response time in the cases where the half moon was presented along with the polygon, identifying Wux (see Figure 2.4c). On average, the result would be a slower response time for the latter one-unique plus one-shared condition – relative to the one-unique case – but not because the increase in the encoding-retrieval match led to a more difficult discrimination problem as such. The slower response time would be better attributed to the response conflict that the strategic processing of the shared cue set up. If the slower performance in one-unique plus one-shared condition can be attributed solely to this, then the critical finding for the memory-as-discrimination view (one-unique plus one-shared slower than one-unique) has to be re-evaluated.

Strategic processing of shared cues: A test

The correct responses in the one-shared condition were examined to determine which of the two possible targets was selected in each trial. Even if it is obligatory to choose one of the two possible targets in each one-shared trial, this should not necessarily mean that the same target should be selected. When presented with only a shared cue at test (one-shared condition), 70% of the participants (19 out of 27) almost always selected the same target, although there were two possible correct answers (*systematic strategy group*). This was true for both shared cues, which means that two targets - called hereafter *favoured* - were selected more than the other two - called hereafter *non-favoured* - in the one-shared condition. A minority of participants (30%, n=8) did not adopt the above strategy (*weak strategy group*). One participant did not favour any targets in reference to the shared cues; the two possible targets were evenly selected in each one-shared test condition. The remaining seven participants favoured one target for one of the shared cues, but they evenly linked the other shared cued to both of the other two targets. In this case, the strategy was still observable but to a lesser extent. We measured the number of times that each target was selected in the presence of a shared cue. Figure 2.5 illustrates the number of times each target was selected in the one-shared condition for the systematic strategy and the weak strategy group; the maximum number that each target could be selected in the one-shared conditions was 12. If selection was evenly distributed, then each target would be selected six times per shared cue. However, the systematic strategy group favours two of the four targets, while target selection in the weak strategy group was somewhat less skewed.

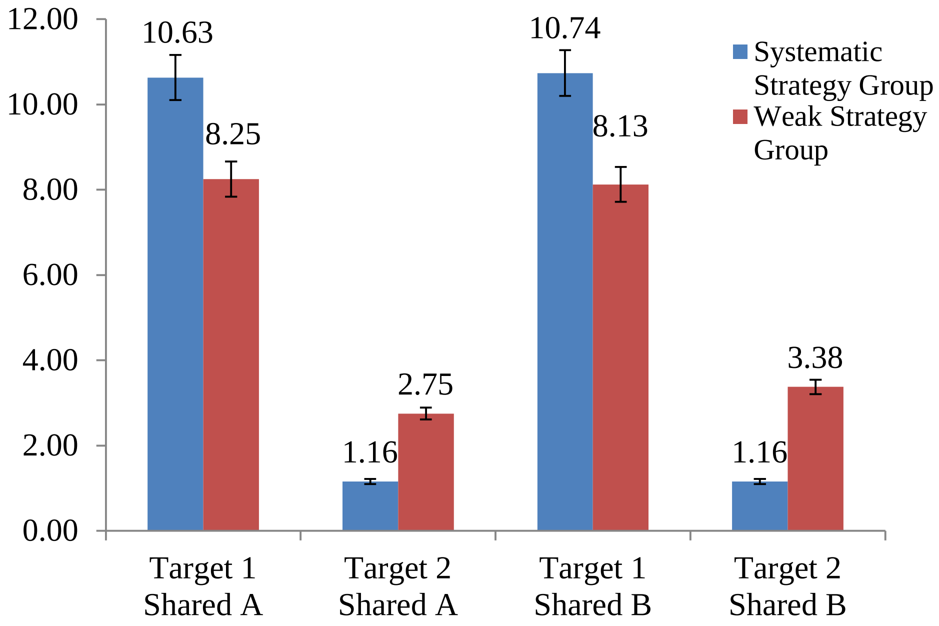


Figure 2.5 Mean number of times a target was selected in each one-shared condition (shared A, or shared B) across participants in the systematic strategy and in the weak strategy group.

We tested whether the systematic strategy group significantly selected two targets compared to the weak strategy group. A 2x2x2 mixed ANOVA was performed with strategy group as the between subjects factor (systematic strategy / weak strategy), shared cue (A, or B) and target type (favoured, non-favoured) as the within subjects factors. There was a significant main effect of target type: F (1, 25) = 27,68, P<.001, eta squared = .92 with the favoured ones selected significantly more than the non-favoured ones. A significant main effect of strategy group was found: F (1, 25) = 4.92, p<.05, eta squared = .16 with the systematic strategy group making more selections than the weak strategy group. There was no main effect of the shared cue: F (1, 25) = 1.53, p>.05. There was a significant interaction of target type and strategy group: F (1, 25) = 24.43, p<.001, eta squared =.50. Simple main effects analyses showed that, for both shared cues, the favoured targets were selected significantly more by the systematic strategy group than the weak strategy group. For the shared cue A, the mean favoured target selections for the systematic strategy group was 10.63

(sd=1.57), and for the weak strategy group it was 8.25 (sd=2.96): t (25) =-2.75, p<.05. For the shared cue B, the mean favoured target selections for the systematic strategy group was 10.74 (sd=1.28), and for the weak strategy group it was 8.13 (sd=2.47): t (25) =-3.64, p<.01. Also, for both shared cues, the non-favoured targets were selected significantly less by the systematic strategy group than the weak strategy group. For the shared cue A, systematic strategy group=1.16 (sd=1.60) and weak strategy group=2.75 (sd=2.49): t (25) =1.99, p=.05 and for the shared cue B, systematic strategy group=1.16 (sd=1.25), and weak strategy group=3.38 (sd=1.85): t (25) =3.63, p<.01. In short, the response strategy affects the number of times each target will be selected. It seems that the systematic strategy group favours one target per shared cue (two favoured overall) significantly more than the weak strategy group, while they choose the alternative targets (two not favoured) significantly less than the weak strategy group.

Further analyses were conducted to test whether this response bias had any effect on performance. The question was whether performance for the targets in the critical one-unique plus one-shared condition was affected by the *systematic* target selection strategy. The analysis that follows compares accuracy and response times for the targets that were preferentially selected to performance for the targets that were not selected as much. For this purpose we only examined the systematic strategy group. Since the weak strategy group does not have clear cut selected versus non selected targets, no such comparison can be made. Hence, the eight participants that did not systematically show the bias were excluded, as there was no straightforward way to include them in the analysis. For the 19 remaining participants we identified the favoured and the non-favoured targets. Favoured targets are the CVCs that were consistently selected as responses to the shared cues. This can be determined by examining responses in the one-shared condition. For each target, there were a total of 12 one-shared trials. To be categorised as favoured, a target had to be selected at least eight out of 12 times or more (i.e. 66% of the time or more). Since there were two shared cues, there could be two favoured targets. The non-favoured targets were the remaining two targets. Which two targets were favoured /non-favoured varied across participants. Response choice data showed that all 19 participants repeatedly selected one target over the other in the one-shared conditions; the same (favoured) targets were chosen, on average, in nine out of the 12 selections (75%) [The alternative, non-favoured, targets were chosen on average three times (25%), see Figure 2.5]. In view of this response bias, we hypothesized that accuracy and response time in the one-shared and in the one-unique plus one-shared condition would be superior for the favoured relative to the non-favoured targets. The presence of the shared cue as part of the non-favoured target should impair performance since it creates a response/retrieval conflict.

Accuracy analyses of the systematic strategy group

Figure 2.6 depicts accuracy results for the favoured and non-favoured targets across cue type conditions. Performance was high overall. It seems that for the favoured targets, the one-unique plus one-shared condition was better than the other two while for the non-favoured targets, the two-unique condition showed the highest performance.

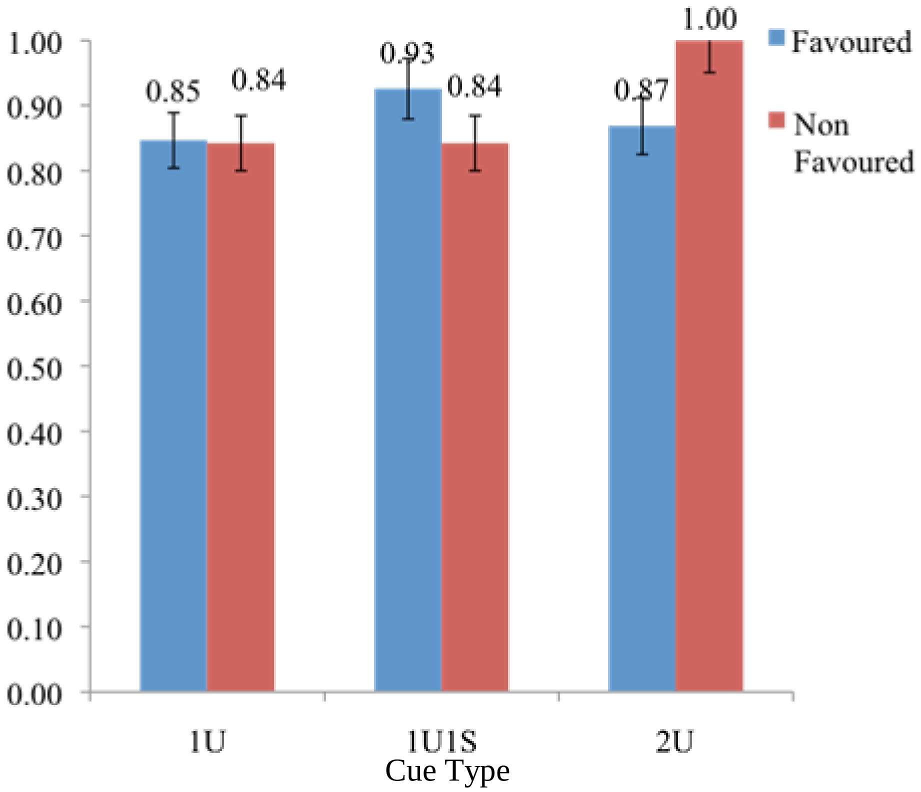


Figure 2.6 Accuracy for favoured and non-favoured targets based on cue type: one-unique (1U), one-unique plus one-shared (1U1S) and two-unique (2U)

A 2 (preference: favoured, non-favoured) X 3 (cue type: one-unique, one-unique plus one-shared, two-unique) repeated measures ANOVA on accuracy showed a significant main effect of cue type: F (2, 36) = 8.34, p<.01, eta squared = .32 matching the findings reported earlier (see Table 2.2). There was no effect of preference: F (1, 18) =.18, p>.05, but there was a significant two-way interaction: F (2, 36) = 11.58, p<.001, eta squared = .40. Simple main effects analyses showed that the cue type effect was different for the favoured and the non-favoured targets (see Table 2.3); for the favoured ones, where the shared cue was closely associated with the target, one-unique plus one-shared condition was significantly more accurate than one-unique (p<.05). Two-unique did not differ from either the one-unique, or from one-unique plus one-shared. For the non-favoured targets, the two-unique condition induced the most accurate performance compared to the other two (p<.001). In this case, one-unique plus one-shared condition did not differ from the one-unique condition (see Table 2.3). In addition, the effect of preference was different for the different cue type conditions. Within the *one-unique condition*, there was no effect: t (18) = .08, p>.05. Within the *one-unique plus one-shared condition* and within the *two-unique condition*, there was a significant effect of preference: t (18) = 2.15, p=.05 and t (18) = -2.64, p<.05 respectively with the favoured targets being more accurate in the one-unique plus one-shared condition and the non-favoured being more accurate in the two-unique condition (see Table 2.3). Paired T-Test on accuracy for the one-shared condition showed that the favoured targets (M=.99, sd=.04) were significantly more accurate than the non-favoured ones (M=.50, sd=.44): t (18) = 4.83, p<.001.

Table 2.3 Accuracy and response time (RT) results based on cue type and preference

		Cue Type Mean (SD)			
		One-unique	One-unique plus one-shared	Two-unique	F-Ratio
Accuracy	Favoured	.85 (.16)	.93 (.11)	.87 (.22)	F (2, 36) = .3.66, p<.05.
	Non Favoured	.84 (.14)	.84 (.14)	1.00 (.0)	F (2, 36) = 15.54, <.001
RT (sec)	Favoured	1.65 (.13)	1.83 (.16)	1.64 (.14)	F (2, 36) = .98, p>.05
	Non Favoured	1.60 (.13)	2.54 (.2)	1.65 (.08)	F (2, 36) = 18.07, p<.01

Response time analyses of the systematic strategy group

Response times (see Figure 2.7) seem to be much slower in the one-unique plus one-shared condition for the non-favoured targets, while differences between favoured and non-favoured targets in the other cue type conditions are small.

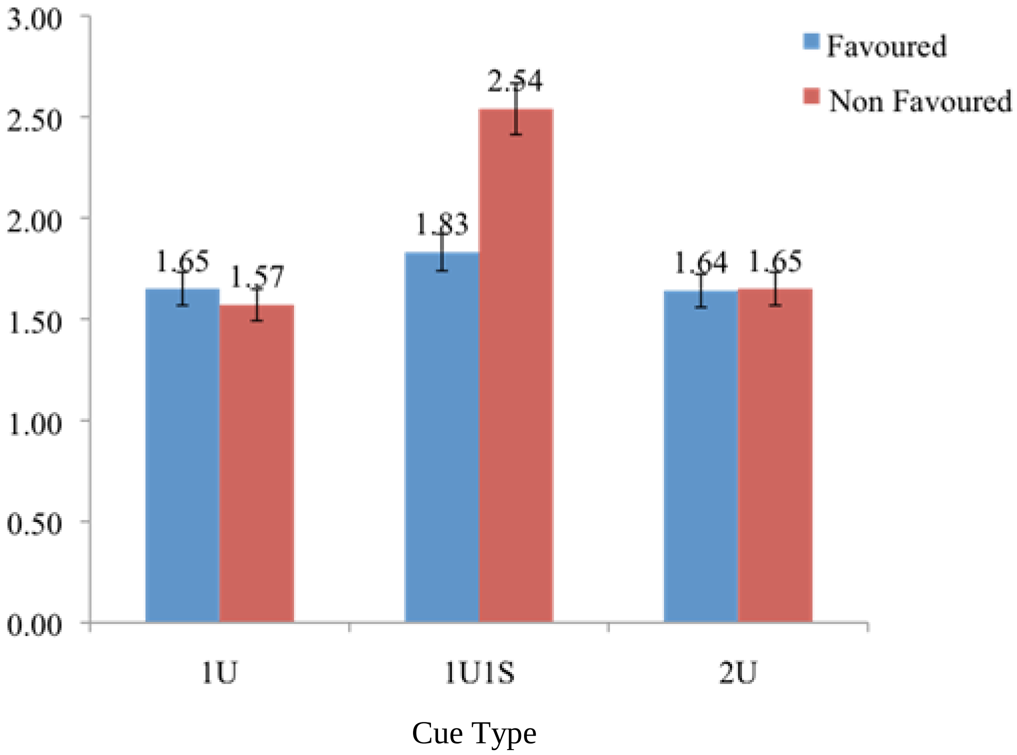


Figure 2.7 Response time for the favoured and non-favoured targets in one-unique (1U), one-unique plus one-shared (1U1S), and two-unique (2U) conditions.

A 2 (preference: favoured and non- favoured) X 3 (cue type: one-unique, one-unique plus one-shared, two-unique) repeated measures ANOVA on response time revealed a significant main effect of cue type: F (2, 36) = 14.48, p<.001, eta squared = .45, matching the results reported earlier (see Table 2.2). There was no effect of preference: F (1, 18) = 2.92, p>.05, but there was a significant two-way interaction: F (2, 36) = 6.89, p<.01. Simple main effects analyses did not show any difference across cue types for the favoured targets. The effect of cue type was only present within the non-favoured targets; one-unique plus one-

Cue Type

shared condition was significantly slower than both one-unique and two-unique conditions. One-unique did not differ from two-unique. The effect of preference was not present within the one-unique condition: t (18) = .54, p>.05 or within the two-unique condition: t (18) = -.07 p>.05. There was a significant effect of preference within the one-unique plus one-shared condition: t (18) = -3.44 p<.01 with the favoured targets being selected faster (see Table 2.3). Paired T-Test on response time for the one-shared condition showed no difference (marginally) between the favoured (M=1.46, sd=.34) and the non-favoured targets (M=1.91, sd=.99): t (11) = -1.99, p=.07.

Accuracy results confirmed our predictions that performance would be better in the one-shared and in the one-unique plus one-shared condition for the favoured targets. Response time was also better in the one-unique plus one-shared condition for the favoured targets. In addition, the cue type effect was only observed for the non-favoured targets. Taken together, these results suggest that the one-unique plus one-shared condition may have been slower not due to the increased discrimination difficulty, but due to the strategic processing of the shared cues.

We also looked at how this bias might have influenced the errors for the one-unique plus one-shared condition. We expected that there would be more mistakes for the non-favoured target than for the favoured ones. In addition, we expected that when the shared cue was presented with a unique cue identifying the non-favoured target, errors would involve the favoured target. The total number of errors for the one-unique plus one-shared condition across participants was 53. There were more mistakes (N=38, 72%) relating to a cue combination that predicted a non-favoured target than one relating to a favoured target (N=15, 28%). Chi-square tests using a hypothetical even distribution (50%-50%) showed a significant difference between the non-favoured target mistakes (72%) and the favoured target mistakes (28%): X2 (1) = 10.17, p<.01. From the overall number of mistakes (N=53), 46 (87%) involved a target that shared a cue with the unselected correct response. Within these errors (N=46), participants were more likely to wrongly select a favoured target (N=32, 70%) instead of the correct non-favoured one. The opposite, selecting the non-favoured target instead for the correct favoured one occurred 14 times (30%). This pattern was significant when compared to a hypothetical even distribution: X2 (1) = 8.33, p<.01. From the overall number of mistakes in one-unique plus one-shared condition (N=53), only seven (13%) did not involve a target sharing a cue; participants wrongfully selected another non-favoured target in six cases (86%) while they mistakenly selected another favoured target once (14%). Again this pattern was significant when compared to a 50%-50% distribution: X2 (1) = 29.78, p<.001. These results further support the idea that participants processed the shared cue as mainly predicting one target (the favoured one). When the shared cue was presented in a cue pair that predicted the non-favoured target, the majority of mistakes involved the favoured target. In addition, in the one-unique plus one-shared condition more errors were made in relation to the non-favoured than the favoured target.

The current study examined two alternative interpretations of the Poirier et.al (2011) findings; the slower one-unique plus one-shared condition could be produced by the strategic cue processing involving either the processing order of the cues in the one-unique plus one-shared condition, or a bias introduced in the processing of the shared cue. We found no support for the first alternative interpretation (the processing order of the cues had no subsequent effect on performance). However, the additional analysis based on target preference selection showed that a response bias could have actually produced the reported pattern of results.

The fact that the condition containing the shared cue (one-unique plus one-shared) was slower appears to have been due to a processing bias whereby most participants preferentially associated the shared cue with one of the two possible targets. This interpretation is supported by the fact that, although overall there was a slower response for the one-unique plus one-shared condition, this was not the case when only the favoured targets were considered—the targets that were consistently selected when the shared cue was presented on its own. For these targets, there was no significant effect of cue type, unlike what either encoding-retrieval match or memory-as-discrimination would predict. These findings are disquieting for the latter view since the experiments that supported its predictions relied on a similar paradigm (see Poirier et al. 2011).

The original interpretation, which suggested that the slower response time in the one-unique plus one-shared condition was attributable to the reduced discrimination power of the cue constellation, is now put to question. It could be the case that previous supporting evidence was a side-effect produced by this response strategy. However, one can ask if this strategy is a recurrent one. If yes, is it possible to manipulate it? Exp.2 tried to answer these questions.

2.4. Experiment 2

Exp.2 had two main objectives. The first was to replicate the findings of Exp.1 with respect to the strategic processing of the shared cue (response bias/strategy). The second was to attempt to manipulate or control which target would be selected as the favoured response.

We used a simpler task where each of the four CVC trigram targets was associated with two cues instead of three; a unique shape and a shared one. In the previous experiment, participants, when presented with a shared cue, showed systematic preference for a given target, but it would seem that they selected which target would be favoured at random. We hypothesized that the presence of a distinctive unique cue for two of the four targets would influence participants' choice (see Figure 2.8). Underwood, Ham and Ekstrand (1962) suggested that participants, when faced with a complex or compound stimulus, would select one of its components to use as an effective cue for the response (functional cue). Rabinowitz and Witte (1967) explored whether a single distinctive element of a multiple element stimulus would be selected to become the effective cue for response elicitation. They created lists containing seven paired-associates; each pair was composed of consonant-trigram stimuli with numbers (ranging from one to seven) as responses. One of the trigram letters was red while the other two were black. In a transfer task, there was a significantly higher performance (more correct responses) when the red letter was presented. It seems that participants use a single distinctive element (the red letter) of a multiple element nominal stimulus as the effective cue for responding. These results suggest that participants' tendency to use the initial stimulus as a functional one is exaggerated when a part of it is more distinctive (see Jenkins, 1963). Based on this, we expected participants to select the unique and distinctive shape as the functional / preferred cue for the relevant targets. We further expected the shared shape to become a cue for the targets that were not associated with a unique distinctive cue (see Figure 2.8 for an illustration of the expected response strategy), especially as the shared cues and the unique non-distinctive cues all shared multiple features (i.e. simple shapes, colour filled).

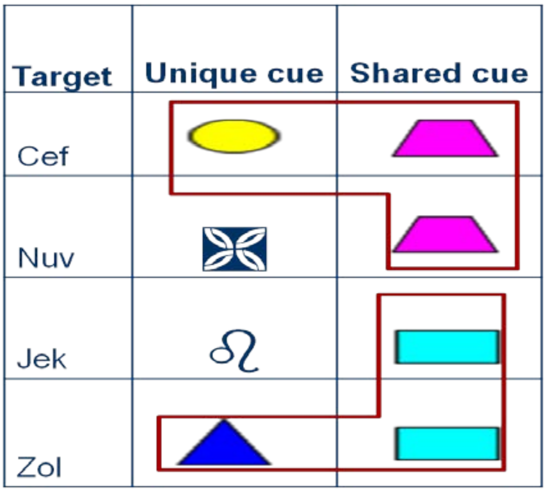


Figure 2.8 Stimuli used and expected strategy. We expect participants to associate the shared cues more strongly with the target that does not include a unique distinctive cue (i.e. Cef or Zol).

2.4.1. Method

2.4.1.1. Participants

Sixty-nine participants (37 Female and 32 Male) contributed to this study with a mean age of 37.6 (SD = 8.12). The study was conducted online and participants were recruited through the I-Points rewards system (a loyalty program allowing people who respond to surveys to earn points that can be later exchanged for rewards). To ensure the validity of results, instructions required from participants to close any other programs and to download the program on their own machine. Results were automatically uploaded to a secure webpage when the task was completed. No two participants with the same IP address were accepted. Also, a minimum task duration of 20 minutes and a maximum task duration of 30 minutes were set a priori, based on pilot testing with the task.

2.4.1.2. Design and Materials

The task called upon here was a simplified version of the one used in Exp.1 and lasted for about 25 minutes. The targets were once again four CVC trigrams only this time two shapes were used as cues for each; one of the shapes was unique to the target and the other was shared between two targets. In total, we created four simple and light coloured shapes (each in a different colour) and two more complex shapes, one in black and the other in dark blue. The last two were always used as unique cues for two of the four targets (see Figure 2.8). Everything else (i.e. randomizations, shape/trigram sizes) were the same as in Exp.1.

2.4.1.3. Procedure

The procedure was the same as in Exp.1 with the three separate phases; learning, training and test. During training, one block included 12 trials testing the following conditions three times each: one-shared, one-unique, one-unique plus one-shared and two-unique. Once again, participants had to reach a 75% correct performance criterion for each condition before they could proceed to the test phase. During test, six blocks were administered resulting in a total of 72 trials (24 per testing condition). The number of correct and incorrect responses was recorded, as well as median response time for correct trials (in milliseconds-ms).

2.4.2. Results and Discussion

All participants exceeded the 75% correct performance criterion in all conditions. We examined, once more, whether the order of cue presentation in the one-unique plus one-shared condition had any effect on the response time results (*cue processing order interpretation*). The one-unique plus one-shared trials were divided into those that involved one-unique cue to the left of the screen, and those that involved one-shared cue presented to the left. A repeated measures T-Test comparing these one-unique plus one-shared conditions showed no significant difference in response time: t (51) = 1.22, p>.05, shared on the left: M=1.48 (sd=.42), and unique on the left: M=1.44, (sd=.40).

Since in Exp.1 response time seemed to vary as a function of preference, we also examined cue processing order in favoured and non-favoured targets separately. Repeated measures T-Tests showed no significant difference in response time depending on the position of the shared cues for the favoured targets: t (51) = .887, p>.05, shared on the left: M=1.58, (sd=.61), and unique on the left: M=1.52, (sd=.54), nor for the non-favoured targets: t (51) = .560, p>.05, shared on the left: M=1.38, (sd=.41), and unique on the left: M=1.36, (sd=.43). Results replicated those in Exp.1; the results show no evidence validating the first alternative interpretation.

An examination of the raw data revealed the existence of a response bias similar to the one observed in Exp.1 (*strategic cue processing interpretation*) for the majority of participants (52 out of 69 or 75.4%). When presented with the one-shared cueing condition at test, these participants preferentially selected one of the two possible targets / responses (*systematic strategy group*). So, as an example referring to Figure 2.8, “zol” was selected in most trials when they were presented at test with a light blue rectangle, despite the fact that “jek” was also a correct response. The distinctive cues seem to have contributed to the strategy, as predicted, by creating a structure within the cue set. Response choice data in the one-shared condition showed that within the systematic strategy group, 83% of participants selected the targets that did not include a distinctive unique cue (on average 11 selections out of 12 per target), as shown in Figure 2.8 (*systematic strategy group a).* The remaining participants within the systematic strategy group (17%) favoured targets in a more random manner; they selected the target with no distinctive cue for one of the shared cues, but then selected the target with the unique distinctive cue for the other shared cue (*systemantic strategy group b*).

A minority of participants (17 out of 69, 24.6%) did not follow the above strategy. Five participants did not favour any targets in reference to the shared cues and in the one-shared condition at test they evenly selected the two possible correct targets (*no strategy group*). The remaining 12 participants adopted the strategy just for one of the shared cues, while they evenly linked the other shared cued to both of the other two targets. In this case, the strategy was still observable but to a lesser extent (*weak strategy group*). Figure 2.9 illustrates the number of times each target was selected in the one-shared condition for both systematic strategy groups, for the weak and for the no strategy group. In case there was no bias, each target should have been selected on average six times. While both systematic strategy groups clearly favoured two of the targets, target selection in the weak strategy group was less biased and no biased at all in the no strategy group.

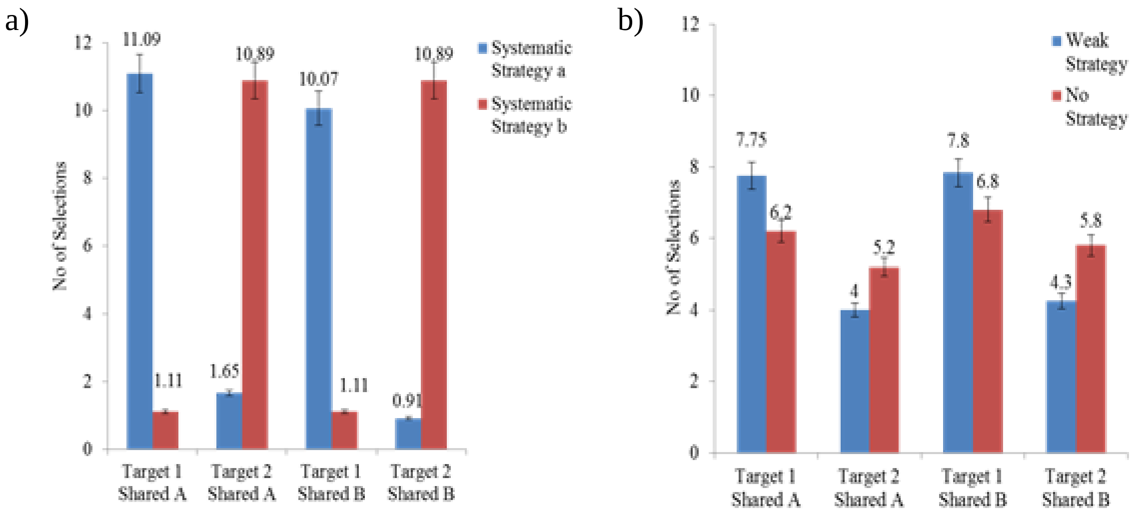


Figure 2.9 Mean number of times a target was selected in each one-shared condition (shared A, or shared B) across participants in a) the two systematic strategy groups and b) in the weak and no strategy groups.

To test whether the *systematic* group significantly selected two targets compared to the weak strategy group, we collapsed the two systematic groups together on the one hand and the weak and no strategy groups on the other. A 2x2x2 mixed ANOVA was performed with strategy group as the between subjects factor (systematic strategy groups collapsed /weak and no strategy groups collapsed), shared cue (A, or B) and target type (favoured, non-favoured) as the within subjects factors. There was a significant main effect of target type: F (1, 67) = 485.76, p<.001, eta squared = .88 with the favoured targets being selected significantly more than the non-favoured ones. There was no effect of shared cue: F (1, 67) = 2.67, p>.05 or strategy group: F (1, 67) = 0.28, p>.05. There was a significant interaction of target type and strategy group: F (1, 67) = 86.11, p<.001, eta squared =.56. Simple main effects analyses showed that, for both shared cues, the favoured targets were selected significantly more by the systematic strategy group, than the weak strategy group. For shared cue A, the mean favoured target selection in the systematic strategy group was 10.19 (sd= 1.73) and in the weak strategy group it was 8.00 (sd=2.15): t (67) = -4.27, p<.001. For shared cue B, the mean favoured target selection in the systematic strategy group was 11.07 (sd= 1.18) and in the weak strategy group it was 7.76 (sd=2.22): t (67) = -7.90, p<.001. Also, for both shared cues, the non-favoured targets were selected significantly less by the systematic strategy group, than the weak strategy group. For shared cue A, systematic strategy group=1.57 (sd= 1.61), and weak strategy group=3.88 (sd=2.20): t (67) = 4.65, p<.001, and for shared cue B, systematic strategy group=.92 (sd= 1.19), and weak strategy group=4.2 (2.22): t (67) = 7.90, p<.001. Once again, it seems that the response strategy affects the number of times each target was selected.

For the same reasons as in Exp.1, we excluded the participants that did not adopt a strategy (*no strategy group*), or that adopted the strategy for half the targets (*weak strategy group*). For the remaining participants (n=52), we identified the favoured and the non-favoured targets based on the responses in the one-shared condition. The criterion, as before, was set to eight or more selections from a possible of 12; response choice data showed that, on average, one target was selected in 10 out of 12 times. If a target was selected less than eight times in the one-shared testing condition, it was classified as non-favoured. Since there were two shared cues, there would be two favoured targets. The predictions were the same as in Exp.1; responses for the favoured targets were expected to be faster and more accurate than for the non-favoured ones in the conditions including the shared cue (tests involving one-shared and one-unique plus one-shared cue).

Accuracy analyses of the systematic strategy group

Figure 2.10 illustrates the accuracy results for each condition based on preference. Accuracy was high in all cue type conditions for the favoured targets reaching ceiling in the one-unique plus one-shared cueing condition. Accuracy was high in the one-unique and in the one-unique plus one-shared conditions for the non-favoured targets, but very low in the one-shared condition.

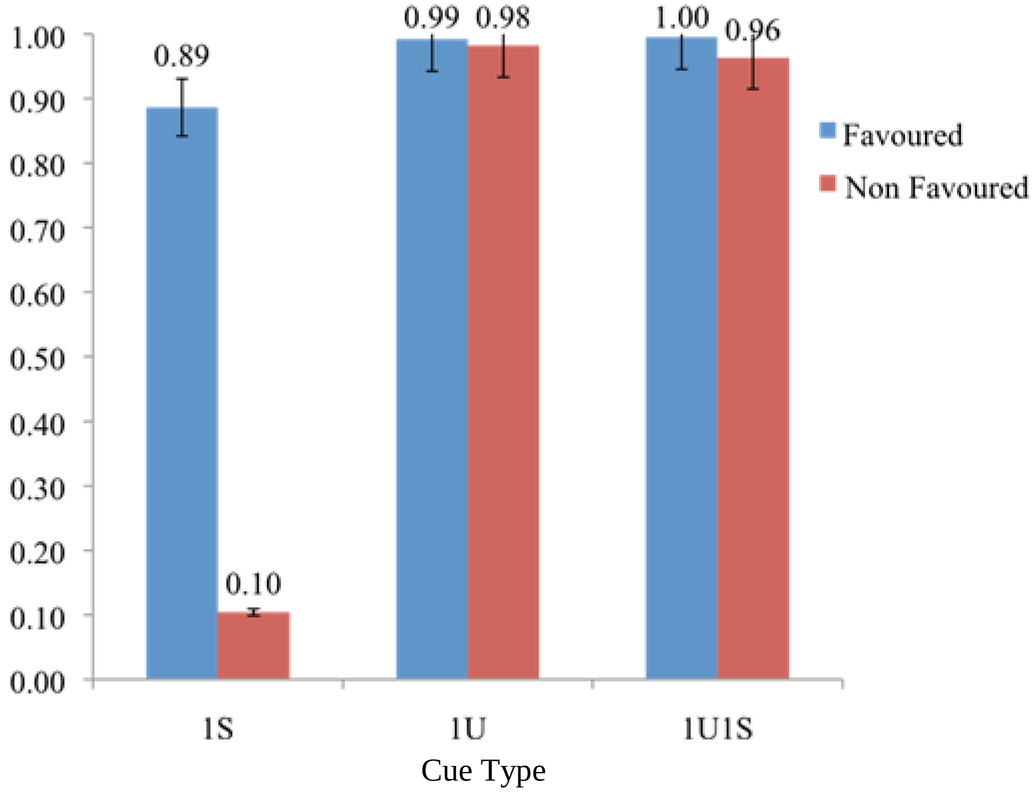


Figure 2.10 Accuracy results for favoured and non-favoured targets for one-shared (1S), one-unique (1U) and one-unique plus one-shared (1U1S) conditions.

A 2 (preference: favoured and non-favoured) X 2 (cue type: one-unique, one-unique plus one-shared) repeated measures ANOVA on accuracy revealed a significant effect of preference: F (1, 51) = 12.51, p<.01, eta squared=.20 with the favoured targets (M=.99, sd=.03) being more accurate than the non-favoured ones (M=.97, sd=.06). The two-way interaction was marginally significant: F (1, 51) = 3.87, p=.05, eta squared = .7. The effect of cue type was only present for the non-favoured targets with one-unique plus one-shared condition being less accurate than one-unique. The effect of preference was not significant for the one-unique condition: t (51) = 1.35, p>.05. There was a significant effect of preference in the one-unique plus one-shared condition: t (51) = 3.49, p<.01 with the favoured targets being more accurate (see Table 2.4). Paired T-Test on accuracy for the one-shared condition showed that favoured targets were significantly more accurate than non-favoured: t (51) = 31.98, p<.001.

Table 2.4 Accuracy and response time (RT) results based on cue type and preference

		Cue Type Mean (SD)			
		One-shared	One-unique	One-unique plus one-shared	T-Ratio [one-unique vs. one-unique plus one-shared]
Accuracy	Favoured	.89 (.09)	.99 (.03)	1.00 (.03)	t (51) = -.49, p>.05
	Non-Favoured	.10(.09)	.98 (.04)	.96 (.07)	t (51) = 2.06, p<.05
RT (sec)	Favoured	1.32(.32)	1.24 (.33)	1.23 (.26)	t (51) = .34, p>.05
	Non-Favoured	1.98(.84)	1.31 (.40)	1.42 (.46)	t (51)= -3.14, p<.01

We also examined how the response bias might have influenced the errors in the one-unique plus one-shared condition. Based on our previous findings, we expect that there will be more mistakes for the non-favoured targets. Also, we predicted that errors would involve the target that was related to the same shared cue. The total number of errors in the one-unique plus one-shared condition was 27; most errors (n=24) were mainly related to a cue combination that predicted a non-favoured target rather than a favoured one (n=3).

From the overall number of errors (n=27), 20 (74%) involved a target that had the same shared cue. Within this type of error, we found the same trend as before; participants were more likely to wrongly select a favoured target instead of the correct non-favoured one (n=17). The opposite, selecting the non-favoured target instead for the correct favoured occurred three times. From the overall number of mistakes in one-unique plus one-shared condition (n=27), only seven (26%) did not involve a target sharing a cue; participants wrongly selected another non-favoured target in seven cases while they never selected another favoured target. The above results provide additional support to the idea that participants mostly process the shared cue in relation to the favoured target. Participants made fewer mistakes in the one-unique plus one-shared condition regarding those targets. Also, the majority of mistakes for the non-favoured targets involved the favoured target that was sharing a cue.

Response time analyses of the systematic strategy group

Response time results, as illustrated in Figure 2.11, suggest that there is no difference between cue type conditions for the favoured targets, while one-shared condition is the slowest for the non-favoured targets, followed by the one-unique plus one-shared condition. Overall, the favoured targets appear to be faster than the non-favoured ones.

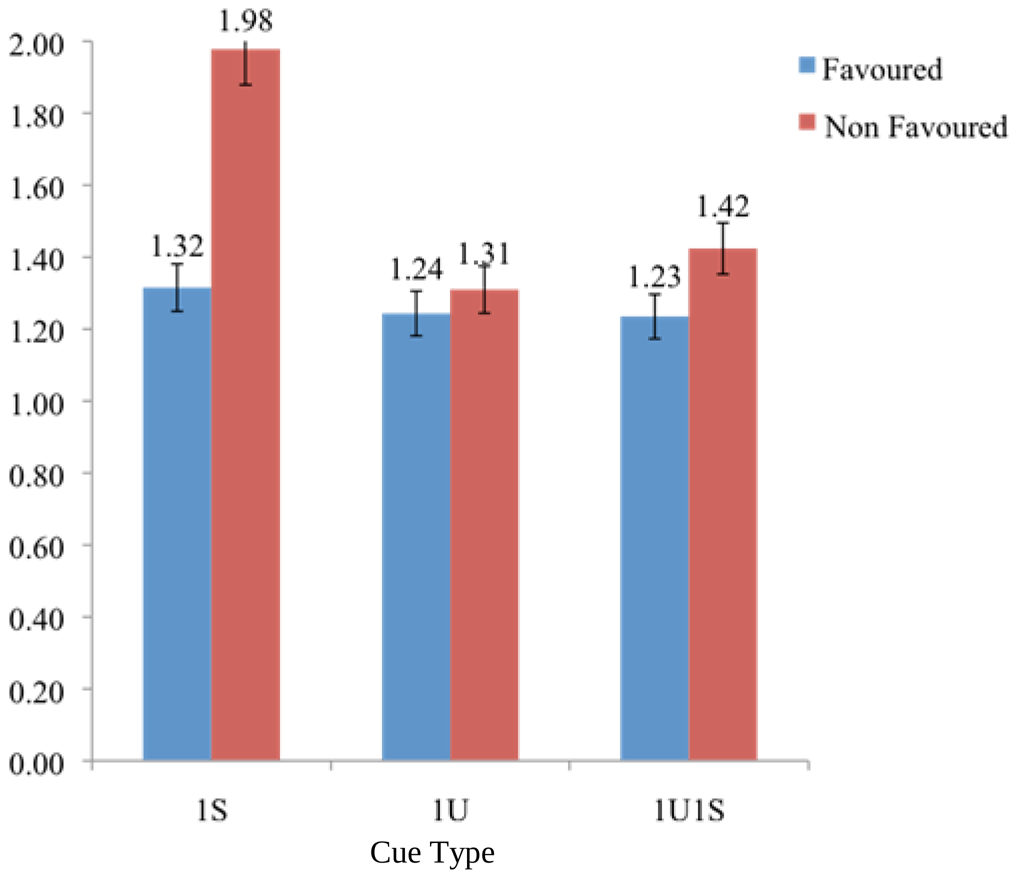


Figure 2.11 Response time for favoured and non-favoured targets for one-shared (1S), one-unique (1U) and one-unique plus one-shared (1U1S) conditions.

A 2 (preference: favoured and non-favoured) X 2 (cue type: one-unique, one-unique plus one-shared) repeated measures ANOVA on response time revealed a significant main effect of cue type: F (1, 51) =5.56, p<.05, eta squared = .10 with one-unique plus one-shared condition (M=1.33, sd=.36) being slower than one-unique (M=1.28, sd=.37). There was a significant effect of preference: F (1, 51) = 14.42, p<.001, eta squared = .22 with the favoured targets being significantly faster (M=1.24, sd=.30), than the non-favoured (M=1.37, sd=.43). The two-way interaction was also significant: F (1, 51) = 8.01, p<.01, eta squared=.14. The effect of cue type was only present for the non-favoured targets with one-unique plus one-shared condition being slower than one-unique. The effect of preference was significant for both one-unique condition: t (51) = -2.16, p<.05, and for the one-unique plus one-shared condition: t (51) = -3.98, p<.001 with the favoured targets inducing faster responses (see Table 2.4). Paired T-Test on response time for the one-shared condition targets showed that favoured targets were significantly faster than non-favoured: t (36) = -5.64, p<.001.

Exp.2 replicated Exp.1 results and confirmed that a response bias was influencing the results; the one-shared condition was more accurate and faster for the favoured targets. In the critical one-unique-plus-one-shared condition, cueing the favoured targets led to more accurate and faster performance, than cueing the non-favoured targets. The one-unique plus one-shared condition may have been slower in previous studies due to the strategic processing of the shared cues rather than because of its reduced discriminative power. In addition, we were able to predict which targets would be selected as favoured for the majority of the participants who showed this bias. The next necessary step to test the memory-as-discrimination predictions would be to eliminate the response bias observed.

2.5. Experiment 3

The goal of this last study was to test the critical predictions of memory-as-discrimination once the response bias identified in Exp. 1 and 2 was eliminated. The first aim was to ensure that participants processed the shared cues as predicting both the targets they were associated with. For this purpose, a new training task was implemented making it unlikely that the strategic processing of the shared cues would occur. In every other aspect, this experiment used stimuli and a design that was similar to what was used previously.

2.5.1. Method

2.5.1.1. Participants

Eighteen City University students (four male and 14 female) took part in this study with a mean age of 19.4 (SD=0.86). This sample provides sufficient power (.90) to detect small differences. They were rewarded with either one course credit or £5.

2.5.1.2. Design and Materials

The stimuli used were ten simple shapes as in Exp.1, each one in a different light colour, and four CVC trigrams as targets. Each target was associated with three shapes (cues); one of the cue-shapes was always shared between two targets (shared cue), while the other two cue-shapes were unique to a target (see Table 2.5). The same controls as in the previous two experiments took place to ensure the validity of the results. The number of correct and incorrect responses was recorded as well as response time (median response time for correct trials only).

Table 2.5 Stimuli used in Exp.3

Cef			
Zol			
Jek			
Nuv			

2.5.1.3. Procedure

The study consisted of the same learning, training and test phases like before. The learning phase was exactly the same as in the previous two experiments. However, the training now included two different stages. The first was a drag-and-drop task: the participants were presented with one target at a time, in the middle of the screen, with all the cue-shapes presented in a line at the top of the screen (see Figure 2.12). Participants had to drag-and-drop the shapes that corresponded to the target shown into three response boxes in any order they chose.

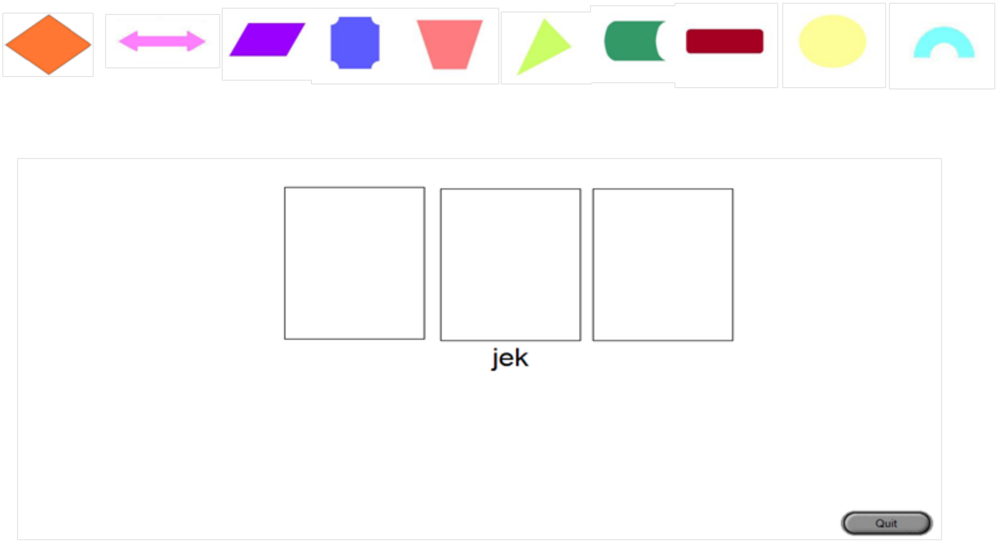


Figure 2.12 Illustration of the drag-and-drop task. The participants had to drag-and-drop in the boxes the corresponding shapes from the top of the screen to the target shown in the middle

In case they made a mistake, they got feedback along with the correct combination of shapes. Then, the shapes at the top of the screen were shuffled and the participant had to respond to that specific target again. This task ended only when participants dragged and dropped the correct cue-shapes for all the four targets four times in a row.

During this stage of the task, participants were instructed that the order with which they selected the shapes is not important as long as their choices were the correct ones. Nevertheless, the program recorded which shapes were selected as first, second or third choice. These additional data could provide further insight into the differential treatment of the various cues types; for instance, we could observe whether participants selected the more discriminative cues (the unique cues) first.

The second training task, practice test, was the same as the actual test presented later on. This phase started with a final reminder of which cues predicted which target as in the learning phase. Then, participants were presented with 32 test trials with cue presentations testing the following conditions eight times each (twice per target): one-shared, one-unique, one-unique plus one-shared and two-unique. On each trial, participants were asked to select the correct target by clicking as quickly as possible on the appropriate response button. After the completion of all trials, the participants were shown the targets and cues simultaneously again, as a reminder. This was repeated until they reached a 75% performance criterion in each condition. The difference from the previous experiments lied in the one-shared condition. In the past, when participants were presented with one-shared shape, both of the two possible correct answers were available; if their responses were correct, they reached the criterion. This was central to the response bias as participants usually focused on one target per shared shape and neglected the other possible answer. In order to prevent this from happening, when testing the one-shared condition, we presented participants with only three response buttons including only one of the correct targets each time (see Figure 2.13). On a random 50% of the one-shared trials, one of the correct targets was part of the answer buttons, while the other half of the trials, the other correct target was presented. Participants had to reach the performance criterion separately for each one of these targets.

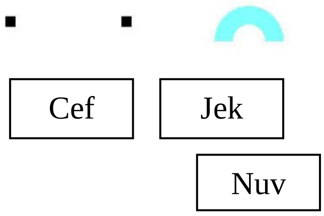


Figure 2.13 The critical one-shared condition at test. Just three targets were presented so that there is only one correct response.

During the test phase, the participants were shown the same 32 trials, repeated four times (four test blocks) resulting in a total of 128 test trials. Again, for the one-shared condition there were only three response buttons including only one of the two correct answers each time.

2.5.2. Results and Discussion

All participants exceeded the 75% correct performance criterion in each condition. Before running any other analyses, we wanted to confirm that the response bias uncovered in previous experiments was eliminated. When biased, participants processed the shared cue as if it mainly predicted one of the two possible targets. If participants are biased in the current paradigm, they will be more accurate and/or faster in the one-shared condition and in the one-unique plus one-shared condition for one of the two targets associated with the shared cue. In order to verify that this did not happen, we identified the targets that shared a cue; we then examined whether accuracy or response time was different for one of the two targets in the one shared and in the one-unique-plus-one-shared conditions. If our manipulation was effective and the response bias was eliminated, then we should find no significant difference.

Response Strategy Elimination Check

Paired T-Tests were conducted separately for accuracy and response time within each pair of targets sharing a cue (pair A, pair B). For the one-shared condition, the accuracy and speed with which the two correct targets were selected within each pair was compared. Repeated measures T-Tests showed no significant difference in accuracy between the targets of pair A: $t(17) = 1.46$, $p>.05$ or of pair B: $t(17) = .00$, $p>.05$. The same was true for response time for pair A: $t(17) = -1.15$, $p>.05$ and for pair B: $t(17) = -1.89$, $p>.05$. In the case of the one-unique plus one-shared condition, the speed and accuracy with which an answer was selected for the conditions sharing the same cue within each pair were compared. Repeated measures T-Tests showed no significant difference in accuracy between the targets of pair A: $t(17) = .44$, $p>.05$ or of pair B: $t(17) = -.37$, $p>.05$. The same was true for response time for pair A: $t(17) = 1.40$, $p>.05$ and for pair B: $t(17) = -.85$, $p>.05$. Participants responded as accurately and as quickly in all one-shared and in all one-unique plus one-shared conditions regardless the specific target tested (see Table 2.5); these results suggest that participants did not favour a specific target when they encountered a shared cue.

Table 2.6 Accuracy and response time (RT) for each target pair in one-unique and in one-unique plus one-shared conditions.

	One-shared condition		One-unique plus one-shared condition	
	Accuracy	RT	Accuracy	RT
	Mean (sd)	Mean (sd)	Mean (sd)	Mean (sd)
Target 1 Pair A	1.00 (0.00)	2.07 (0.77)	0.98 (0.05)	1.93 (0.81)
Target 2 Pair A	0.96 (0.12)	2.43 (1.64)	0.97 (0.07)	1.74 (0.67)
Target 1 Pair B	0.99 (0.04)	1.82 (0.75)	0.97 (0.07)	1.62 (0.46)
Target 2 Pair B	0.99 (0.04)	2.24 (1.02)	0.98 (0.06)	1.69 (0.43)

Drag-and-drop results

In the drag-and-drop task, participants were required to drag-and-drop the shapes that corresponded to the target shown into three response boxes (see Figure 2.12). Instructions indicated that the cue selection order would not affect performance, as long as the correct cues were placed in the response boxes. Overall, across positions and participants, there were 864 selections (288 selections for each of the three positions). Interestingly, response patterns revealed that participants preferred to select certain types of cues first, second or third: participants' first and second selections were mostly unique cues, while their last selection was mostly the shared cue. Figure 2.14 reveals how many times (%) each cue type was selected first, second or last during the drag-and-drop task.

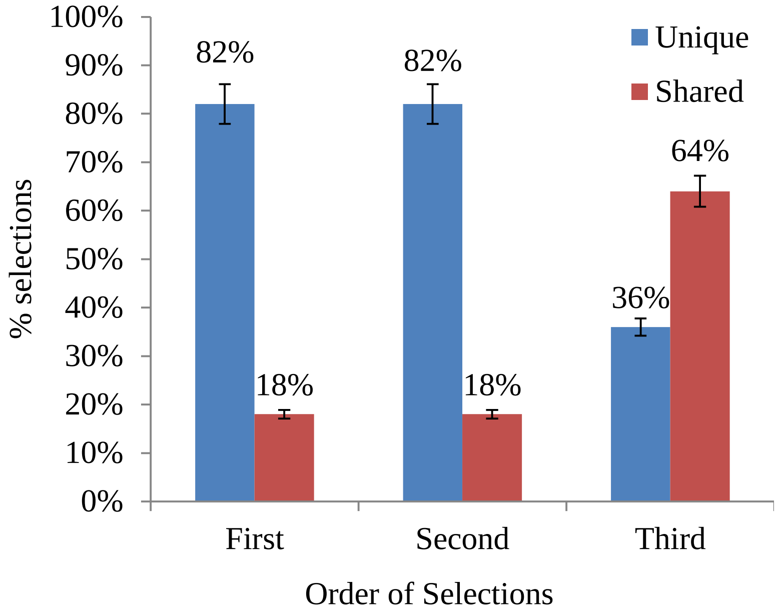


Figure 2.14 First, second or third selection choices (%) for the unique and shared cue.

A 2x3 repeated measures ANOVA with cue type (unique, shared) and position (first, second, third) as factors showed a significant two-way interaction: F (2, 34) = 17.06, p<.001, eta squared = .50. Simple main effects analyses showed significant differences in the number of times a cue was selected in each position as a function of its type. In the first position, significantly more unique cues (M=13.11, sd=3.46) were selected than shared (M=2.89, sd=3.46): t (17) = -6.26, p<.001. In the second position, significantly more unique cues (M=13.17, sd=2.43) were selected than shared (M=2.83, sd=2.43): t (17) = -9.02, p<.001. In the third position, significantly less unique cues (M=5.72, sd=4.56) were selected than shared (M=10.28, sd=4.56): t (17) = 2.12, p<.05. These results suggest that the nature of the cue and the information it holds in terms of predicting the target played a role in the selection order. More specifically, it seems that the cues that are more discriminative (unique) are selected either first or second.

Memory-as-discrimination predictions tested

Accuracy seems to be equal across the cue type conditions. Response time seems slower in the one-unique plus one-shared conditions relatively to the other two. One-unique appears to be equally fast to two-unique (see Table 2.7).

Table 2.7 Mean (SD) accuracy and response time (RT) for each cue type: one-unique, one-unique plus one-shared and two-unique.

	Cue Type Mean (SD)		
	one-unique	one-unique plus one-shared	two-unique
Accuracy	.99 (.04)	.98 (.03)	1.00 (.01)
RT (sec)	1.53 (.37)	1.76 (.53)	1.47 (.32)

A repeated measures ANOVA (cue type: one-unique, one-unique plus one-shared, two-unique) on accuracy showed a non-significant main effect of cue type: F (2, 34) = 1.63, p>.05. A repeated measures ANOVA (cue type: one-unique, one-unique plus one-shared, two-unique) on response time showed a significant main effect of cue type: F (2, 34) =5.96, p<.01, eta squared = .26; one-unique plus one-shared condition was significantly slower (M=1.76, sd=.53) than one-unique condition (M=1.53, sd =.37) and two-unique condition (M=1.47, sd =.32). There was no difference between one-unique and two-unique.

Exp.3 eliminated the response bias identified in previous experiments and supported the memory-as-discrimination predictions; one-unique and two-unique conditions were equally fast, despite the increase in encoding-retrieval match. On the other hand, the addition of a shared cue (one-unique plus one-shared condition) to the one-unique condition, despite the increase in encoding-retrieval match, resulted in a significantly slower performance compared to the other two conditions. This effect cannot be attributed to longer processing time due to the presence of two cues instead of one, since there was also a significant difference between one-unique plus one-shared and two-unique condition.

2.6. General Discussion

Our objective in this chapter was to evaluate alternative interpretations of the Poirier et al. (2011) findings. Exp.1 and 2 replicated their findings; increasing the match by adding a cue that was shared amongst two targets (going from one-unique to one-unique plus one-shared) had no impact on accuracy, but was sufficient to significantly slow down performance. Going from one-unique cue to two-unique cues (an increase in encoding-retrieval match without any change in the discrimination power) saw accuracy increase. Moreover, response time was slower in the one-unique plus one-shared condition than the two-unique. However, the slower one-unique plus one-shared condition could have been a by-product of the order in which the cues were processed in that condition at test (shared cue or unique cue first). Exp.1 and 2 found no support for this alternative interpretation. Results demonstrated that the cues' processing order had no effect on response time in the one-unique plus one-shared condition; trials where the shared cue appeared first were undistinguishable from the trials were the unique cue appeared first. It seems that participants do not ignore the shared cue in the one-unique plus one-shared condition, but they base their response on both cues.

Further analyses of the response protocols indicated that a response bias was confounding the results, providing a second alternative interpretation. The fact that the one-unique plus one-shared condition was slower appears to have been due to a processing strategy, whereby most participants preferentially associated the shared cue with one of the two possible targets. In the one-shared condition, at test, most of the participants neglected one of the correct responses and they focused, most of the times, on just one of the two. This bias created two sets of targets; the favoured targets, which the shared cue came to mostly predict, and the non-favoured targets that were rarely selected as a response to the shared cue – even though they were also a correct choice. In the one-unique plus one-shared condition, the shared cue could be presented along with a unique cue that defined a favoured target as the correct response, or with a unique cue that defined a non-favoured target. In the latter case, the unique cue points unequivocally towards the non-favoured target, while the shared cue points mostly in the direction of the favoured target. The resulting conflict can lead to slower response times on these trials. This interpretation was supported by our findings in both Exp.1 and 2; for the favoured targets, there was no difference in response time, or accuracy between one-unique and one-unique plus one-shared condition. For the non-favoured targets, the one-unique plus one-shared condition was significantly slower, and less accurate, than the one-unique condition. In addition, the favoured targets were found to lead to more accurate and faster performance than the non-favoured targets in the one-unique plus one-shared condition. Taken together, Exp.1 and 2, clearly suggest that it was the response strategy, rather than the reduced discrimination power of the cues, that was responsible for the difference reported between the one-unique plus one-shared and the one-unique condition.

Exp.3 implemented a procedure that ensured the elimination of the observed response bias, and found evidence in favour of the memory-as-discrimination view; when the increase in match was achieved at the expense of the discrimination power of the cue combination, performance suffered; when the increase involved adding a second unique cue, performance was little affected. The notion that encoding-retrieval match leads to better recall is not supported in our results. Our findings, as well as those of Poirier et al. (2011) and Goh & Lu (2012), suggest that the capacity of a cue to discriminate between potential targets should be considered as the only predictor of performance. It was shown that less information was more effective when it was more diagnostic of the retrieval target. As stressed by Nairne (2001, 2002, 2005, 2006) , it seems that an increase in the encoding-retrieval match can have no effect, can support retrieval or hinder performance depending on the relationship between that increase, the target and the competing retrieval candidates. Our findings support the view that cues' discrimination power is crucial for successful retrieval.

The strategic cue processing exemplified in Exp. 1 and 2 provides additional support for this. It appears that the discriminative value of each cue influenced the way in which it was processed, and also led to the development of the response bias / strategy; the strategic processing of the relationship between the shared cue and each of the two targets it predicted (originally, or from the experimenters perspective), in effect transformed the shared nominal cue. Hence, this strategic processing appeared to be an effort to reduce the number of associations some cues shared resulting in more discriminative functional cues. Moreover, in Exp.2, we were able to influence which targets would be the favoured ones with the use of distinctive unique cues. It was expected that, when available, the unique distinctive cue would be selected as the functional cue for that target, and that the shared cue would mostly be associated with the target that had no distinctive cue. Results confirmed this with the majority of the participants in the systematic strategy group adopting this pattern. This finding is in line with Rabinowitz and Witte's (1967) results demonstrating that participants use a single distinctive element from a multiple element nominal stimulus as the effective cue for responding.

Based on the current findings, one could say that when a shared (overloaded) cue is processed with a given target, a certain "weight" is attached to that cue which subsequently modulates the competition at retrieval. The simplified Luce choice rule (1959) that was used to illustrate the memory-as-discrimination view does not take into account the strategic cue processing, and any resulting predictive weight, that further differentiates each cue-target relationship. On the contrary, each cue-target comparison is equally weighted in the process; it is assumed that a cue's features are compared to the relevant targets within the retrieval set, and that retrieval probability of a given cue-target pair is determined by the relative distinctiveness of their link. However, the repeated selection of a target, when a shared cue is presented, as observed in Exp. 1 and 2, can be seen as modifying the weight of that cue-target pair, relative to the other cue-target comparisons involving the said cue. As the number of times a target is retrieved in response to a shared cue increases, the 'weight' of the shared cue-target comparison could be seen as increasing as well. In theory, response time in the one-unique plus one-shared condition should vary as a function of the shared cue's weight; the more weight a cue acquires, the faster the response times it will elicit.

Looking back at Exp.1 and Exp.2, we created two data sets taking into consideration the weight of the shared cues. As we have mentioned before, the total number of selections in the one-shared condition during testing was 12. If, in that condition, the participant selected the same target at least eight times, that target was considered to be favoured. The suggestion is that a shared cue-target pair would have a greater weight, when the shared cue presented alone, led to the selection of that specific target 12 times compared to a case where that target was chosen eight times. The graphs below (see Figures 2.15 and 2.16 for Exp.1 and Exp.2 respectively) describe how the response time in the *one-unique plus one-shared* condition varies as a function of the number of times a target was correctly selected in the *one-shared* condition (0-never selected, 12-always selected). Both graphic representations show response time decreasing as the number of selections – or 'weight'- increases.

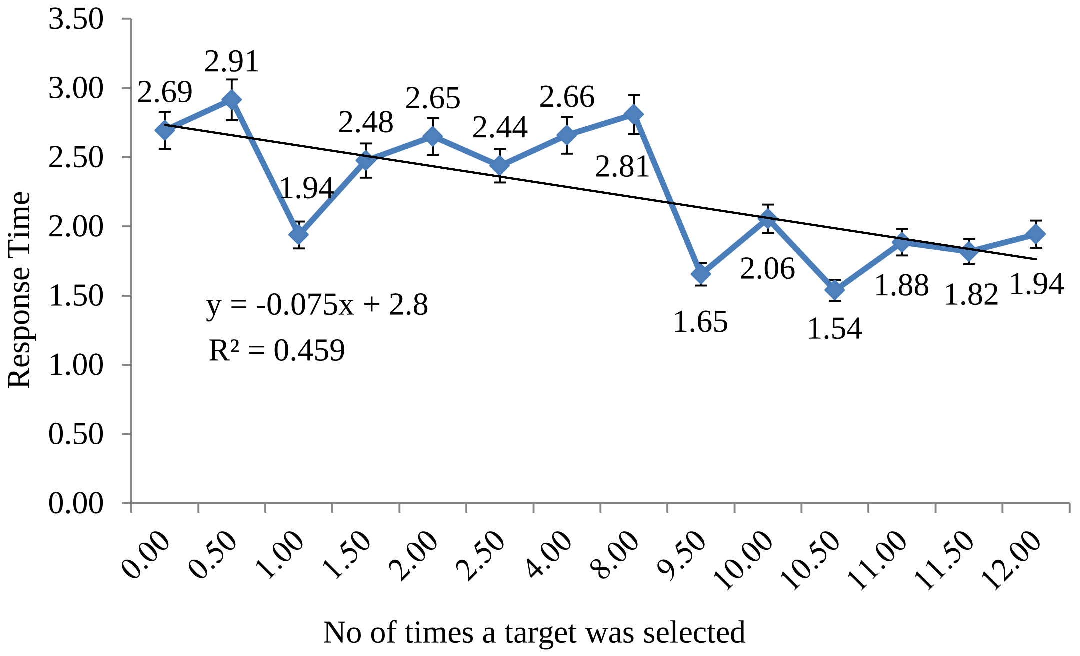


Figure 2.15 Exp.1 - Response time in the one-unique plus one-shared (1U1S) condition based on the number of times a target was selected in the presence of a shared cue (0-never selected, 12-always selected).

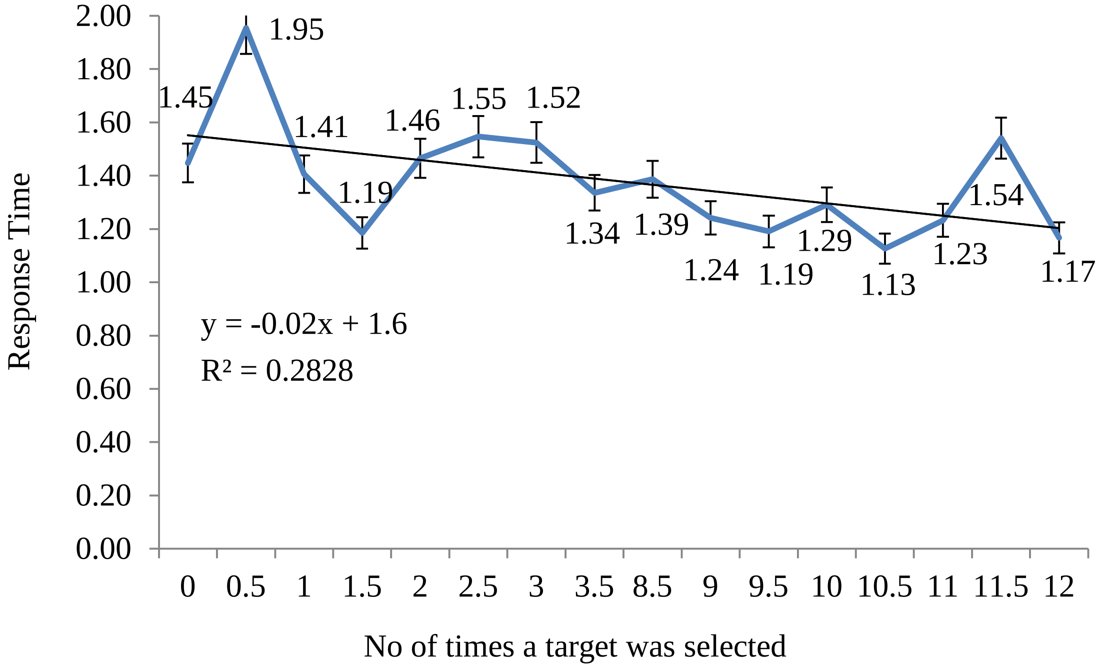


Figure 2.16 Exp.2 - Response time in the one-unique plus one-shared (1U1S) condition based on the number of times a target was selected in the presence of a shared cue (0-never selected, 12-always selected).

An interesting observation was that, even after the elimination of the response bias, the participants, given the chance, favoured the more discriminative cues. This was evident in Exp. 3, when we examined the order in which the cues were selected during the drag-and-drop task; on most trials, participants did not select the shared cue until after they had put one, or both, unique cues into place. The order of cue selection within the drag-and-drop task seems to further support the memory-as-discrimination view; participants favour the cues whose discriminative power is superior. An implication is that the diagnostic value of a cue influences its processing, and may result in prioritising the cues that help solve the discrimination problem involved in retrieval.

In summary, the findings reported here suggest that participants choose to encode / process cues in ways that modulate the discrimination problem posed to the memory system. When considered in detail, the above findings suggest that participants actively avoid cue overload, if the experimental set-up allows them to do so; given the opportunity they selectively process the relationships between shared / overloaded cues and targets in such a way as to actively transform nominally overloaded cues into functional cues that are more discriminative. If one considers that cue overload reduces the value of a cue in terms of predicting an outcome, then these findings may be seen as an adaptive choice: people spontaneously choose to supress some relationships (e.g. the ones that are not supported by feature similarity) in order to preserve the predictive value of a cue; associating each shared cue preferentially to a given target (and altering the cues' weights) in effect transformed a non-discriminative cue into a cue that supported the retrieval of a correct target. Participants' effort to increase the shared cues' diagnostic value can be seen as further indirect support for the memory-as-discrimination view which stresses the importance of the discriminative power of the cues. In general, it appears that processing is systematically biased towards more discriminative features in the environment. The memory-as-discrimination view could lead to more accurate predictions if a formula was proposed to account for possible weighting that the cues may acquire due to their processing.

Chapter 3:

Active Cue Processing in a Memory-as-discrimination Paradigm

Note to examiners: the introduction in this chapter repeats some of the material found in the general introduction chapter. This was difficult to avoid within the context of a PhD presented in journal article form.

3.1. Abstract

Nairne (2001, 2002) stated that what matters most for successful retrieval is the diagnostic value of the cues present at test, and their power to identify the correct target from within the set of competing items. The main goal of the three experiments reported here was to explore how a cues' diagnostic value and discrimination power might affect its processing pattern and guide functional cue selection. The distinction between nominal cues (what the experimenter thinks is encoded) and functional cues (what the subject actually encoded) has long been established (Capaldi & Neath, 1995; Neath, 1998; Postman, Stark & Fraser, 1968). The original information can be distorted in a variety of ways (Neath & Surprenant, 2003). In previous paradigms, participants developed a response strategy, apparently to increase the discrimination power of ambiguous cues (Koutmeridou et al., 2011). The literature on distinctiveness suggests that a distinctive cue can be more predictive of a target than a less distinctive one. Hunt and his colleagues (Hunt, 2003; Hunt & Lamb, 2001; Hunt & McDaniel, 1993; Hunt & Smith, 1996; Smith & Hunt, 2000) have consistently argued that distinctiveness provides an advantage at the point of retrieval, as it separates items in memory from one another more effectively. For this reason, in all three experiments we called upon a distinctive cue that identified two targets (shared cue). Exp.1's findings suggest that the distinctive cues are favoured in terms of processing over the non-distinctive one. This led to a *preferential processing hypothesis*: cues with increased ability to discriminate among targets (discrimination power), such as distinctive cues, receive increased processing. Eye-tracking results (Exp.2) showed that participants spent more time processing the distinctive than the non-distinctive shared cues. However, surprisingly, retrieval performance did not reveal a distinctiveness effect in either study. We hypothesized that strategic processing of cues – i.e. preferential processing that varied depending on retrieval conditions-- could have masked the expected distinctiveness effect. Exp.3 yielded supporting evidence for this hypothesis. Taken together, our findings indicate that the cue’s discrimination power appears to be one of the guiding forces in cue processing, and in the transformation of nominal to functional cues.

Keywords: Functional cues, Nominal cues, Cue Overload, Distinctiveness, Cue Processing

3.2. Introduction

Though the distinction between nominal and functional cues has been established (e.g. Capaldi & Neath, 1995), it remains unsure what guides this transformation. The hypothesis tested here is that a cues' discrimination power might affect the processing it will receive and it will determine whether it will be selected as a functional retrieval cue. What is ultimately stored in memory does not only depend on the available material and its characteristics, but also on the characteristics of the learning context and on the identification and processing of the stimuli. Tulving and Thomson (1971) referred to all the factors present at the time of learning, other than the event, that influence encoding as 'cognitive environment'. The way the learning material is processed has been shown to be a critical determinant of subsequent memory performance (e.g. Sohn, Anderson, Reder and Goode, 2004). The specific processing of the information determines which cues will be effective in eliciting the correct response assuming a future memory test or retrieval attempt. What an experimenter considers as an important retrieval cue can only be thought of as a nominal retrieval cue. The components of the nominal stimulus that the participant actually encodes (and any further processing of that cue that involves knowledge or other stored information) become the effective cue for response elicitation and constitute the functional cue (Capaldi & Neath, 1995; Neath, 1998; Postman, Stark & Fraser, 1968; Underwood, 1963). The physical characteristics of an object may not change, but what is perceived differs depending on the observer's point of view. A retrieval cue is now thought to be the product of a person's mental activity during encoding, but also during retrieval; depending on these activities the same stimulus may have different cueing functions (e.g. Mathews, 1977). Processing the available information within a specific cognitive environment determines the nature of the functional cue either by adding, or subtracting from the nominal cue (Neath & Surprenant, 2003).

Underwood, Ham and Ekstrand (1962) suggested that participants in a memory task, when faced with a complex or compound cue, would select one of its components/features to use as an effective cue for the response (functional cue). These authors assumed that, because of cue selection, there would be a discrepancy between the nominal and the functional cue. For example, learning in a paired-associate task, where the cue was composed of two components, can occur in different ways depending on the cue selection. Since both components are always present during encoding, each component could function as an independent cue, or the effective cue could be their combination. Support for cue selection was provided by verbal reports where participants described how they used part of the originally presented stimulus as a cue e.g. a single letter out of a three-letter stimulus (Underwood and Schulz, 1960).

Assuming cue selection occurs—if only a part of a compound cue becomes the functional cue—what are the cue features that are selected in order to construct the functional cue? More importantly, what are the forces driving the nominal cue's transformation into a functional cue?

One attribute that has been thought of affecting cue selection is meaningfulness (Solso, 1968). Underwood et al. (1962) asked whether the more meaningful component of a compound cue would become the functional cue. They presented two lists of compound cues, consisting of a verbal unit and a colour patch, paired with numbers as targets. In one of the lists, the verbal units were low–meaning trigrams (non-words) while in the other they were common three-letter words. Following one perfect recitation of the lists (initial learning lists), a second paired-associate list was given to the participants, including just part of each compound cue along with new targets (transfer list). Overall there were four groups with a different combination of initial and transfer paired-associate lists (initial list + transfer list): 1) word-colour + colour, 2) word-colour + word, 3) trigram-colour + colour and 4) trigram-colour + trigram. In addition, there were two control conditions: 5) word-colour + word-colour and 6) trigram-colour + trigram-colour. Assuming that colours are more meaningful than non-word trigrams, it was hypothesised that the colour would be selected as the functional cue in the first list. However, in the second list, it was expected that words would be selected over colours. It was therefore expected that, if the trigrams were removed from the trigram-colour compound, there would be little effect on paired-associate performance in the transfer list. The opposite, a big negative impact on performance, was predicted if the colour was removed from the same compound. Inversely, for the word-colour compounds, performance would be greatly (and negatively) affected in the transfer list by the removal of the words, but not from the removal of the colours. Results showed that, in the trigram-colour list, colour was indeed the most effective cue in eliciting correct target responses in the transfer list with the removal of trigrams having only a small effect. For the word-colour list, the presence of the words alone in the transfer list induced more correct target responses than the presence of the colours alone. The latter result could be due to participants' preference in general towards verbal material (as opposed to the colour patches used) and not entirely due to their increased meaningfulness. But the preference of colours to trigrams as functional cues was attributed to their higher meaningfulness.

Spear, Ekstrand, and Underwood (1964) replicated the above finding in another paired-associate transfer task using compound cues composed of a trigram and a word. In the initial learning list, there were eight trigram-word compound cues paired with numbers as retrieval targets. Group W was only shown the words as cues on the transfer list and Group T was only shown the trigrams. It was expected that the more meaningful element of the compound (i.e. the word) would elicit the highest performance in the transfer list. Results showed that group W maintained a high level of performance throughout the transfer tests (mean of 75.75 total correct responses). Group T showed a negatively accelerated learning curve and was overall significantly below group W (mean of 52.08 total correct responses). This finding suggests that cue selection occurred and that the most meaningful element of the compound cue was preferentially processed. It seems that the more meaningful a stimulus is, the more probable it is that it will be selected as a functional cue.

Another attribute thought to be affecting cue selection is the formal similarity of the cues' features. Cohen and Musgrave (1966) employed a paired-associate transfer task for which they created six lists of cue-target pairs, with compound cues and single letters as targets. Each compound cue consisted of two nonsense syllables. Each syllable could either have high (H) or low (L) similarity with the other syllables in the list. In a third of the lists, one of the syllables had high formal similarity (H) with other syllables within the cue set and the second syllable had low formal similarity (L) relatively to the other cue syllables (mixed compound lists). In the other third of the lists, the two syllables were both of high similarity (HH) to the other syllables in the list, and the last set of lists consisted of low similarity syllables (LL). They hypothesised that in the mixed compound cue list (HL) the high similarity syllable would be ignored and participants would select the relatively distinctive low similarity syllable and associate it with the response. Results on ease of learning showed that it was easier to learn the low similarity compound lists (LL), followed by the mixed compound list (HL) and then the purely high similarity compound list (HH). In the transfer task, where only one element of the compound was shown, participants gave more correct target responses to the low similarity syllables. Position of the elements also had an effect with those in the first position leading to higher accuracy. A similar result was found by Cohen and Musgrave (1964); low meaningfulness CVCs in the first position of within a compound cue were better learned than when they were in the second position. Participants initially tend to learn the elements in the first position of a compound cue, and later those in the second. If the second position elements are more discriminable, then they are better learned than the ones in the first position.

Rabinowitz and Witte (1967) asked whether a single distinctive element of a multiple element cue would be selected to become the effective cue for target retrieval. They created a paired-associate list with non-overlapping consonant-trigrams as cues and numbers (ranging from one to seven) as targets. One of the trigram letters was red while the other two were black. The position of the red letter (first, second, third) was manipulated between participants. The paired associate transfer task was used to test learning. The learning criterion was two perfect repetitions of the list after which a surprise transfer task followed. Participants were presented with each individual trigram letter and were asked to assign the correct target number. Results did not show any difference in the learning rate of the lists. In the transfer task, there was a significantly higher performance (more correct responses) when the red letter was presented. It seems that participants use a single distinctive element (the red letter) of a multiple element nominal cue as the effective cue for responding. Examination of the letter position revealed that the first group (red letter in the first position) made significantly more correct responses to the red letter than to the black letters but there was no difference between the second black and the third black letter. The second group (red letter in the middle) and the third group (red letter last) did not differ in the number of correct responses across letter position. Taken together, these results suggest that participants may tend to use the first cue as the functional one and this tendency is exaggerated when it is more distinctive (see Jenkins, 1963).

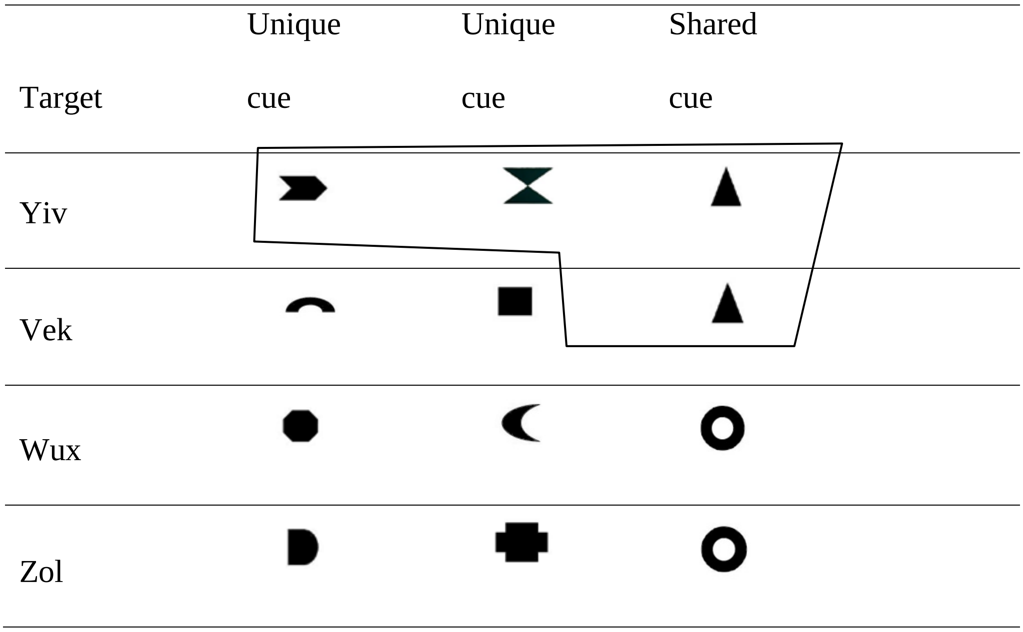
Is there a link between cue selection and cue effectiveness? Our view regards cue effectiveness and cue selection as being both dependent on the degree to which a cue identifies one target to the exclusion of others (discrimination power). One cue may be associated with multiple memory targets, which, in turn, may inhibit the retrieval of a given response to that cue (McGeoch, 1942). Interference could also occur from cue confusion due to coding errors - the cue is encoded in such a way that it cannot be distinguished from another (Runquist, 1975). Successful memory depends on how unique or distinctive the cue-target relationship is.

The idea that memory depends on the relative distinctiveness of the cue-target relationship is not new in the literature (Craik & Jacoby, 1979; Hunt, 2003). For example, the cue overload principle (Watkins & Watkins, 1975) can be thought of as highlighting the importance of a distinct cue-target relationship; if a cue is encoded as part of many events (cue overload), then it is harder for that cue to elicit a single retrieval target (Earhard, 1967; Eysenck, 1979; Watkins & Watkins, 1975; Watkins, 1979; Capaldi & Neath, 1995; Hunt & Smith, 1996). Distinctiveness is viewed in this case to be a relational rather than an absolute concept in that, an object's distinctiveness is always relative to a particular context (Schmidt, 1991). It is not a property of the item in isolation.

According to Hunt (2006), distinctiveness results from the processing of two types of information (Hunt & Einstein, 1981; Hunt & Elliot, 1980): the first is relational information which focuses on the similarities among discrete items within a given set contrasting it to other sets (organizational processing); the second is item-specific information and it stresses the differences among items within a set facilitating discrimination between them. This view suggests that, since the distinctive cue-target relationship is always relative to the particular retrieval context, we need to contrast the relational and the individual item information (*discriminative coding*) to determine cue effectiveness (Einstein and Hunt, 1980). A cue is distinctive to the extent that it specifies a certain target to the exclusion of others (Nairne, 2006). This view of distinctiveness (being a property of a cue in context) is reminiscent of and closely related to the memory-as-discrimination view that stresses the ability of a cue to discriminate among competing targets. Discriminative coding is a process that can potentially attenuate interference (cue confusion and associative interference) by differentiating the cue-target relationships (Runquist, 1975). Runquist, in a series of experiments (1971; 1973b; 1974a; 1975) investigated the establishment of these discriminative cue codes in a paired-associate learning paradigm using a variety of stimuli. Taken together, the findings suggest that learners use the distinctive features of the stimuli to resolve interference that could occur either due to cue confusion or associative competition: 'Essentially, high-similarity stimuli are made into low-similarity stimuli by selective encoding' (Runquist, 1975, p. 148).

In Koutmeridou et al. (2011), a response strategy was revealed that suggested that participants actively re-organise the material to reduce interference (or increase the cues' discrimination power). As Table 3.1 shows the to-be-learned materials were four CVC trigrams associated with three shapes each; two of the shapes were unique to the target (unique cues) and one was shared between two targets (shared cue). Exp.1 of the previous chapter showed that participants systematically linked the shared cues with one of the two possible targets, named the favoured targets (see Table 3.1). When presented with only a shared cue at test, the participants selected one target (favoured) ignoring the other correct response (non-favoured target). This strategy altered the nominal cue-target relationships by attributing a different functional value to the shared cues; the cue overload was functionally reduced as they became predictors, mainly, of one of the two correct targets.

Table 3.1 Response strategy developed during learning (as illustrated in Koutmeridou et al, 2011, pp. 3). In this case, when cued with the triangle, the participant overwhelmingly responded Yiv neglecting the other possibility (Vek).



Target	Unique cue	Unique cue	Shared cue
Yiv	➤	⧗	▲
Vek	⌒	■	▲
Wux	⯃	☾	○
Zol	◗	✚	○

To account for these modulations in the functional value of the cues, models (e.g. the simplified retrieval model presented by Nairne, 2002) would need to be extended or, to include a mechanism for differential weights to be assigned to cue-target relationships. Essentially, the conditions depicted in Figure 3.1 should not differ as each set of cues is equivalent (in both a and b, one cue is uniquely identifying one target, and the other is shared between two targets). Nevertheless, Koutmeridou’s et al. (2011) results showed that response time was faster when the cues were associated with the favoured target (see Figure 3.1a) than when they were part of the non-favoured one (see Figure 3.1b). This result suggests that cue encoding is an active process guided by cue discrimination power. In other words, these preliminary findings suggest that information about a cue’s capacity to discriminate amongst competing targets determines how much processing it will receive, and how its relationship to the target will be managed / processed.

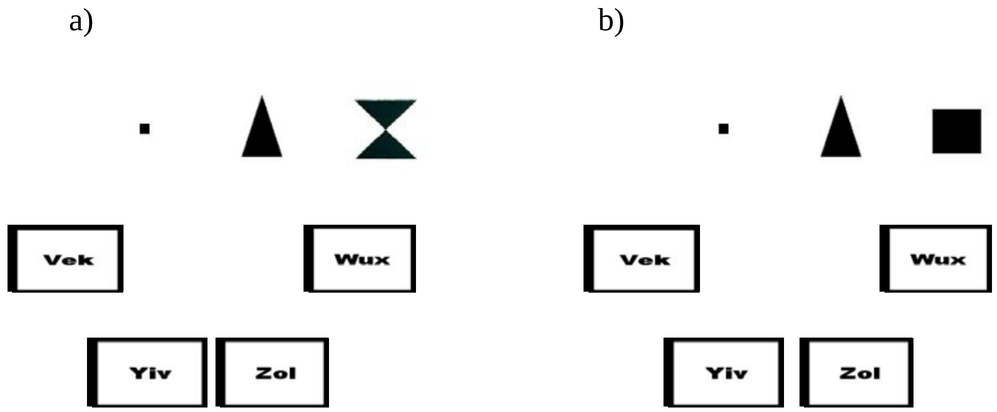
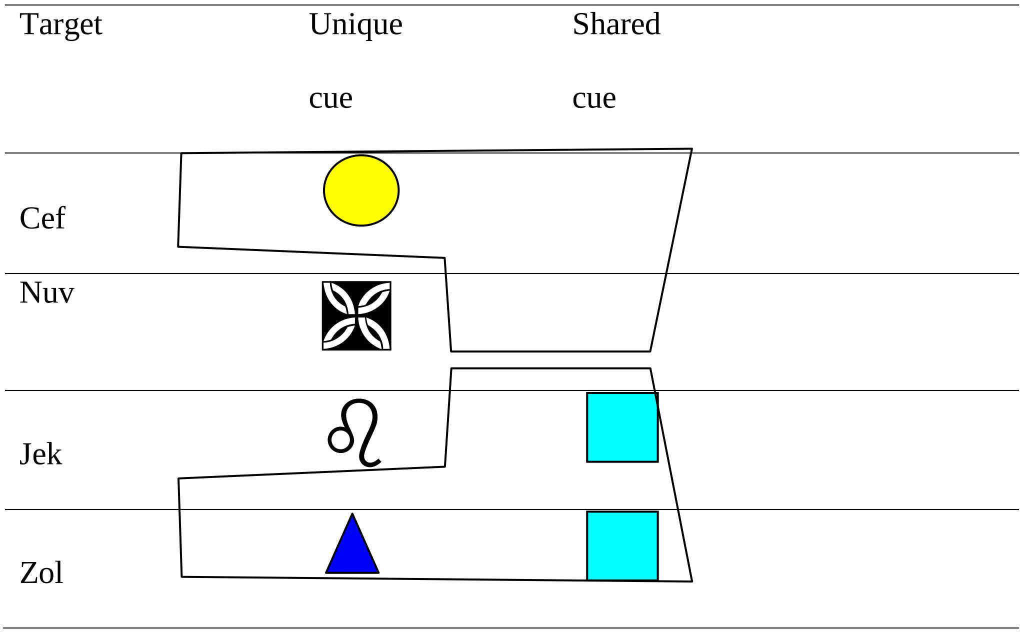


Figure 3.1 a) One-unique plus one-shared condition cueing the favoured target (Yiv) b) One-unique plus one-shared cue condition cueing the non-favoured target (Vek)

Additionally, in Exp.2 of the second chapter the presence of a distinctive unique cue further contributed to the strategy by creating a structure within the cue set (see Table 3.2). The majority of the participants preferred to associate the shared cue with a target that did not include a unique distinctive cue. This pattern seems to be in line with the functional cue selection predictions described above. If participants indeed select the distinctive element of a multiple element stimulus as the effective cue (Jenkins, 1963; Rabinowitz and Witte, 1967) -- in this case the unique distinctive cue -- then it would make sense that the other shared element would be mostly used as a cue for the other target.

Table 3.2 Response strategy observed in Exp.2, Chapter 2: participants associate the shared cues more strongly with the target that does not include a unique distinctive cue.



Target	Unique cue	Shared cue
Cef	●	
Nuv	▩	
Jek	♌	■
Zol	▲	■

Runquist (1975) suggested that participants may select the more discriminative cue features as a functional cue in an effort to reduce interference. It could be the case that those cue features that discriminate among targets the best will be selected to be the functional retrieval cues. This type of processing may be partly responsible for transforming nominally similar cues to dissimilar functional ones.

In this chapter, we make a more systematic effort to shed light onto the ways participants process the learning material. For this purpose, we introduced a distinctive cue[3]. Considering the view of distinctiveness as a relative concept (e.g. Hunt, 2006), there seems to be a consensus that a distinctive cue can become more predictive of the target than a less distinctive cue (Hunt, 2003; Hunt & Lamb, 2001; Hunt & McDaniel, 1993; Hunt & Smith, 1996; Smith & Hunt, 2000). In addition, the pattern of Koutmeridou et al., (2011) results suggests that the presence of a distinctive cue alters the learning material organisation and the

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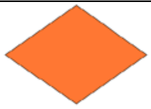
[3] In this thesis, distinctiveness is viewed as a relative concept: an object's distinctiveness is determined by the particular context it is part of.

cue processing dynamics in a predictable manner. Thus, including a distinctive cue will help us observe more clearly if participants process it differently due to its discriminative value.

The cued-recognition task

Poirier et al. (2011) used a cued-recognition task that allows the manipulation of both encoding-retrieval match and cue overload orthogonally and the contrast of the predictions derived from each. All the studies reported in this chapter relied upon the modified version of this task used in Exp.3, Chapter 2. The alterations made were aimed at eliminating the response strategy discussed above. The task consisted of a learning, training and test phase. During the learning phase, the participants had to learn which cues were linked to which targets. The targets were four consonant-vowel-consonant trigrams (CVCs). There were, also, four sets of geometric shapes used as cues; each set contained three shapes. Pre-testing established that task difficulty would be too high if more than four targets and their associated cues had to be learned simultaneously. Table 3.3 below provides the learning material used in our three studies. Some of the cues were shared between two targets (shared cues), whereas others were uniquely associated to one of them (unique cues). One of the shared cues was distinctive (shared-distinctive); while all cues were simple coloured shapes, the distinctive cue was a black and more complex shape. Participants were presented with the four targets and their associated shapes-cues twice. The presentation involved a random selection without replacement of one of the target-cue sets. Each target was presented on screen along with its cues for 10sec and there was a 0.5sec interval before the next one appeared. Participants were asked to pay attention to all cues and to try and learn to which target they corresponded. They were aware that in the test phase, various combinations of cues would be presented and that they would be required to retrieve the correct target.

Table 3.3 Learning material

	Unique Cue	**Unique Cue**	**Shared Cue**
Cef			
Zol			
Jek			
Nuv			

Training included two different stages. The first one was a drag-and-drop task and it was an addition to the original Poirier et al. (2011) task. The participants were presented with one target at a time, in the middle of the screen, with all the cue-shapes presented in a line at the top of the screen (see Figure 3.2). They were asked to drag-and-drop the shapes that corresponded to the target shown into three response boxes. They got feedback along with the correct combination of shapes when they made a mistake. Then, the shapes at the top of the screen were shuffled and the participant had to respond to that specific target again. This task ended only when participants dragged and dropped the correct cue-shapes for all the targets four times in a row. Importantly, the addition of the drag-and-drop task ensured that participants would not associate the shared cue with just one target as they actively had to place it in the response area for both targets.

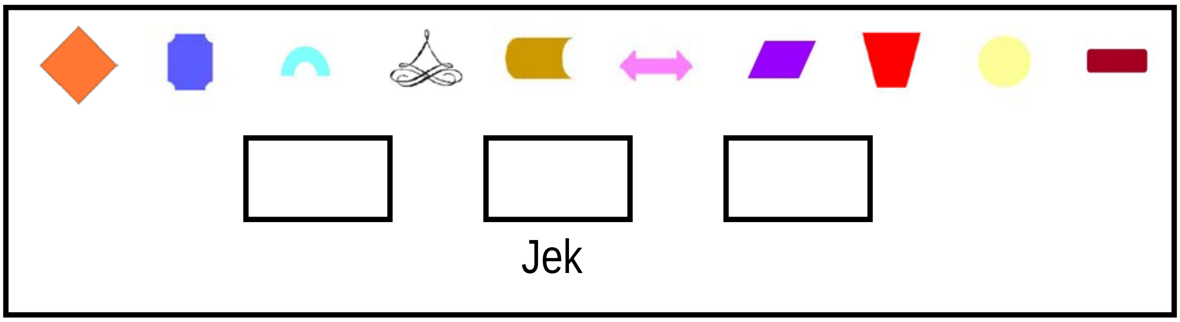


Figure 3.2 Illustration of the drag-and-drop task. The participants had to drag-and-drop in the boxes the corresponding shapes from the top of the screen to the target shown in the middle.

We should stress at this point that participants were instructed that the order in which they selected the shapes did not matter as long as they made the correct choices. However, shape selection order was recorded. It was thought that this information could reveal any choice preference in the absence of task imposed constraints. The choice order pattern might depend on each cue type’s (unique, shared or/and distinctive, standard) discriminative value.

The second training task started with a reminder of the learning phase. Then, cue combinations were presented on screen testing the following conditions: one-shared-standard, one-shared-distinctive, one-unique, one-unique plus one-shared-standard, one-unique and one shared-distinctive and two-unique. Every condition was tested twice per target. In total there were six different conditions but, each target had either a standard-shared cue, or a shared-distinctive cue (see Table 3.3) resulting in 32 test trials per block. For each trial, participants were asked to select the corresponding target by clicking as quickly as possible on the appropriate response button. Response buttons accompanied the presented cues, each identified to one of the retrieval targets. The cues that were not presented were replaced by a small filled square (see Figure 3.3a). Participants had to reach a 75% performance criterion in each condition for two blocks in a row in order to proceed to the actual test. This training phase was necessary to ensure adequate levels of performance during the actual test, which in turn would ensure sufficient encoding of all the different conditions. Hence, any differences observed could not be attributed to insufficient learning of a specific condition, but only to the experimental manipulation.

Figure 3.3 a) One-unique plus one-shared-standard cue test condition, b) one-shared-standard cue test condition.

The second and final alteration of the original Poirier et al. (2011) task occurred in the one-shared-standard, and the one-shared-distinctive testing conditions. In those, participants were presented with just three response buttons including only one of the correct targets each time (see Figure 3.3b). Even though there were only three response buttons, they were located at the same place than when there were four. In 50% of the one-shared trials, the first associated target was part of the answer buttons, and in the other half the other correct target was presented. Participants had to reach the performance criterion separately in each case. This manipulation was central to the elimination of the response strategy (association of the shared cue with just one of the two possible targets) observed in previous versions of this paradigm.

During the actual test phase, the participants were shown the same 32 trials – with no learning prior to it – repeated four times (four test blocks) resulting in a total of 128 test trials.

The number of correct and incorrect responses was recorded, as well as response time (for correct trials only).

3.3. Experiment 4

The main goal of this study relates to the possibility of differential cue processing; the objective was to verify whether the participants process the cues as a function of their discriminative value with respect to the target. It is often not easy to find overt expressions of cognitive processing in a behavioural task - especially when it comes to encoding processing. The cued-recognition task gives us a starting point; the drag-and-drop training task provides us with an insight into the selection order of each cue: we can examine whether there are different selection patterns for cues of different discriminative power. Generally, we expect the more diagnostic cues to be privileged. The unique cue, since it only predicts one target, has increased discrimination power, but is there a difference between the two types of shared cues? The features of the shared-standard cue overlap with those of all the unique cues (simple geometric shapes, all in pastel colours). Because of this, via these features that are by design associated to all the targets, these shared-standard cues will have a link to all the targets (albeit most probably links of varying strength; see Table 3.3). Conversely, the shared-distinctive cues do not have features that are similar to the other cues – hence there is a chance that their link to the irrelevant targets will be weaker. This analysis predicts that the shared-distinctive cues will have more discriminative power than the shared-standard cues. Hence, we predict that the unique and the shared-distinctive cues will be given priority in the drag-and-drop task.

Since we used a distinctive retrieval cue, we also wanted to examine the effect of distinctiveness on memory performance. Accuracy is expected to be higher when a distinctive cue is present, but in terms of response time there are two opposing views: The encoding view predicts that the shared-distinctive cue will produce slower responses, because it will strongly bring to mind both retrieval candidates creating a response conflict when both answers are available. The retrieval view makes the opposite prediction: responses to the shared-distinctive cue will be faster, since it reduces the target pool from four to two. No matter whether the effect is due to encoding or retrieval processes though, a difference between the distinctive and non-distinctive conditions is expected.

A final objective was to ensure the reliability of our previous findings (Exp.3, Chapter 2) as to the elimination of the response strategy and the confirmation of the memory-as-discrimination hypothesis. In sum, the present study was an effort to reproduce the memory-as-discrimination findings in a task that would also investigate the effect of distinctiveness, and more importantly the way people actively process the cues based on their diagnostic value.

3.3.1. Method

3.3.1.1. Participants

Sixty-six participants (34 Female and 32 Male) with a mean age of 36 (SD=8) completed the task. The study was conducted online and participants were recruited through the I-points rewards system (a loyalty program allowing people to earn points by responding to surveys that can be later exchanged for rewards). To ensure the validity of our results no two participants from the same IP address were accepted and a minimum task duration of 20 minutes and a maximum task duration of 30 minutes were set a priori, based on pilot testing with the task.

3.3.1.2. Design and Materials

Participants had to establish an association between sets of three shapes (cues) and a target, as explained in the introduction. In total, there were four targets and four sets of geometric shapes used as cues; nine simple coloured shapes (each one with a different colour) and one more complex shape in black. The latter was used as the shared-distinctive cue for two of the four targets (see Table 3.3 for the complete set of stimuli). The shapes were used as retrieval cues in the memory test and they are referred to here as unique cues, when they were associated with only one target and as shared cues, when they were associated with two of the targets. We used these relatively unfamiliar cues and targets to preclude prior experience with the stimuli from significantly influencing performance. We made sure that the necessary randomisations took place. First, the position of the shapes on screen was random. There were no specific locations for the unique and the shared shapes. Also, the response buttons were randomly placed across participants, but for each participant remained in the same position. Lastly, the creation of associations, such as which shape was shared, or unique, the combination of the shapes, as well as their association to a specific target was randomly determined and different for each participant [with the exception of the more complex black and white shape that was always a shared-distinctive cue].

3.3.1.3. Procedure

The experiment had three different phases: learning-training-test, as described in the introduction. The procedure was the same as in Exp.3, Chapter 2.

3.3.2. Results and Discussion

Before running any other analyses, we wanted to confirm that the response bias uncovered in previous experiments (Exp.1 and Exp.2, Chapter 2) was eliminated. When biased, participants processed the shared cue as if it mainly predicted one of the two possible targets. If participants are still biased in the current paradigm, they will be more accurate and/or faster in the one-shared condition and in the one-unique plus one-shared condition for one of the two targets associated with the shared cue. In order to verify that this did not happen, we identified the targets that shared a cue; target pair A shared a standard cue and target pair B shared a distinctive cue. We, then, examined whether accuracy, or response time was different for one of the two targets in each pair in either the one shared, or/and the one-unique-plus-one-shared conditions. If our manipulation was effective and the response bias was eliminated, then we should find no significant difference.

Repeated measures T-Tests showed no significant difference between the targets in each pair in the one-shared-standard condition either in accuracy: $t(61) = -.65$, $p>.05$, or response time: $t(55) = -.91$, $p>.05$. The same was true for the one-shared-distinctive condition: paired t-test for accuracy: $t(65) = -.70$, $p>.05$ and for response time: $t(60) = 1.09$, $p>.05$. Repeated measures T-Tests showed no significant difference between the targets in each pair in the one-unique plus one-shared-standard condition in accuracy: $t(65) = -.83$, $p>.05$, or response time: $t(61) = 1.37$, $p>.05$. The same was true for the one-unique plus one-shared-distinctive condition: paired t-test for accuracy: $t(65) = -.57$, $p>.05$ and for response time: $t(62) = .51$, $p>.05$.

Participants responded as accurately and as quickly in all one-shared as well as one-unique plus one-shared conditions regardless the specific target tested (see Table 3.4). There is no evidence that they favoured a specific target when they encountered a shared cue.

Table 3.4 Accuracy and response time (RT) for each target pair in one-unique and in one-unique plus one-shared conditions

	One-shared condition		One-unique plus one-shared condition	
	Accuracy	RT	Accuracy	RT
	Mean (sd)	Mean (sd)	Mean (sd)	Mean (sd)
Target 1 Pair A (shared-standard)	0.98 (0.08)	2.35 (1.29)	0.98 (0.05)	2.26 (1.31)
Target 2 Pair A (shared-standard)	0.98 (0.07)	2.54 (1.53)	0.99 (0.04)	1.98 (0.75)
Target 1 Pair B (shared-distinctive)	0.99 (0.05)	2.23 (1.22)	0.98 (0.05)	2.24 (1.02)
Target 2 Pair B (shared-distinctive)	0.99 (0.03)	2.08 (1.04)	0.98 (0.05)	2.13 (0.96)

Drag-and-drop results

In the drag-and-drop training task, participants were required to drag the cues that corresponded to the target shown on screen into three response boxes (see Figure 3.2). All in all, there were 3168 selections to be made across 66 participants; 1056 selections for the unique cues (132 per correct cue-target pair) and 528 for each of the shared cues (again 132 per correct cue-target pair). Each participant had to make 48 selections: 16 for the unique cues and eight for each of the shared cues. There were 12 selections for each position (first, second, or third). Instructions stressed that the cue selection order was unimportant, as long as the correct cues were placed in the response boxes. However, response patterns (for correct trials only) revealed that participants preferred to select certain types of cues first. Figure 3.4 illustrates how many times each cue was selected first, second or last across participants during the drag-and-drop task. The unique cue (U) was equally selected across positions for both targets (containing a shared-distinctive cue or not). The shared-standard cue (S) was selected last more often than first or second (see Figure 3.4b), while the shared-distinctive cue (Sd) was mostly selected first than second or last (see Figure 3.4a).

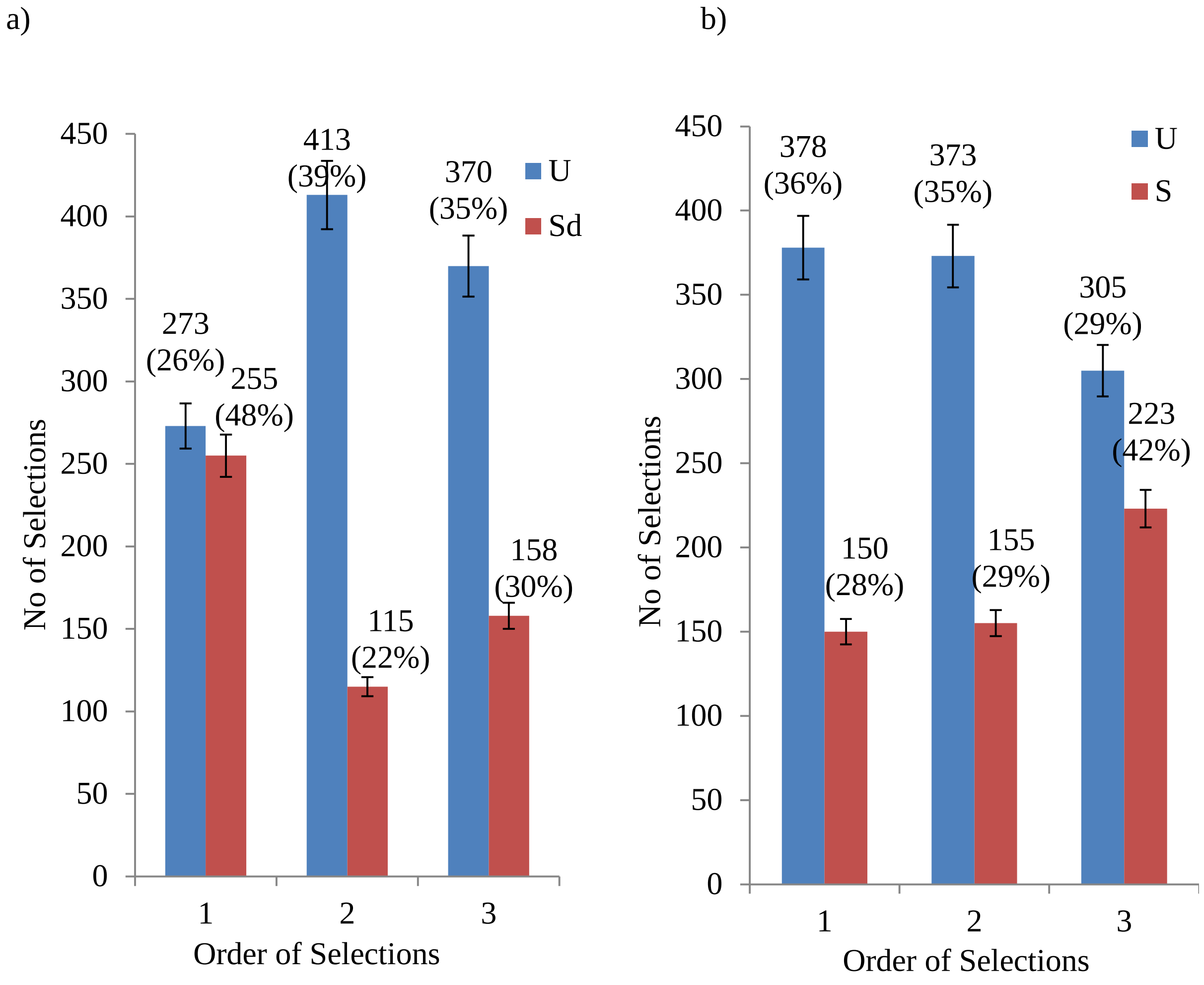


Figure 3.4 Average number of cue selections (and %) as a first, second or third choice for a) targets with a shared-distinctive (Sd) cue b) targets with a shared-standard (S) cue.

A 2 (distinctiveness: distinctive, non-distinctive) x 2 (cue type: unique, shared) x 3 (cue selection position: first, second, third) repeated measures ANOVA was performed on the average number of selections for each position per participant [note: there were 12 selection in each position per participant]. A three-way significant interaction was found among cue type, distinctiveness and position: F (2,130) = 7.93, p<.01, eta squared = .05. Simple main effects analyses showed different selection patterns depending on whether a target included a shared-distinctive cue or not. For targets with a shared-distinctive cue, the unique cues were selected significantly less in the first position (M=4.14, sd=2.97) than in the second (M=6.26, sd=2.37), or third (M=5.61, sd=2.54). The shared-distinctive cues were selected significantly more in the first position (M=3.86, sd=2.97) than in the second (M=1.74, sd=2.37), or third (M=2.4, sd=2.54)]. In addition, there was no difference between unique (M=4.14, sd=2.97) and shared-distinctive cues selected (M=3.86, sd=2.97) in the first position: t (65) =.37, p>.05. More unique cues (M=6.26, sd=2.37) than shared-distinctive (M=1.74, sd=2.37) were selected in the second position: t (65) =7.74, p<.001 and third position (unique =5.61, sd=2.54, shared-distinctive=2.39, sd=2.54): t (65) =5.13, p<.001.

For targets with a shared-standard cue, the unique cues were selected significantly less in the third position (M=4.62, sd=2.53) than in the first (M=5.73, sd=2.39) or second (M=5.70, sd=2.04). Shared-standard cues were selected significantly more in the third position (M=3.38, sd=2.53) than in the first (M=2.27, sd=2.39), or second (M=2.35, sd=2.04). In addition, more unique (M=5.73, sd=2.39) than shared-standard cues (M=2.27, sd=2.39) were selected in the first position: t(65)=5.87, p<.001 and in the second position (unique=5.65, sd=2.04, standard shared=2.35, sd=2.35): t(65)=6.57, p<.001, while this difference was marginally significant in the third position: t(65)=1.99, p=.05, unique=4.62, sd=2.53, shared-standard =3.38, sd=2.53.

The selection patterns of the shared-standard and shared-distinctive cue appear to follow opposite directions; the shared-standard cue is mostly selected last while the shared-distinctive is mostly selected first (see Figure 3.4). A shared-distinctive cue is hypothesised to be more discriminative than the shared-standard cue, as it does not share features with any of the other cues. We hypothesized that this would result in the creation of a subset of two retrieval targets [from amongst four] that would be more clearly related to the shared-distinctive cue. It appears that the nature of the cue and the information it provides relative to the target may play a role in the order in which it is selected. More specifically, it seems that the cues that are more discriminative (unique or shared-distinctive) are preferred over the shared-standard cues.

Memory-as-discrimination analyses

The elimination of the response strategy makes it possible to test the memory-as-discrimination hypothesis and contrast it to strict encoding-retrieval match predictions. Each cue combination used in the test phase represented a specific level of encoding-retrieval match and discrimination difficulty. If a single cue is present, then the encoding-retrieval match is less than if there were two cues present. Similarly, if the presented cue is shared with another target, the difficulty of the discrimination necessary is increased.

All participants achieved high accuracy performance exceeding the 75% performance criterion in all conditions during the test phase. Response time for correct trials only was used. We eliminated response times that were above or below two standard deviations from each participant’s mean and we, then, calculated their median response time per condition [as there were few trials per cueing condition (N=32) this was a means of reducing noise and unwanted variability]. Then we averaged the response time per condition across participants (see Table 3.5). The one-shared condition was not included in the memory-as-discrimination analyses as only three response buttons were present, unlike the rest of the conditions.

Table 3.5 Accuracy and response time results based on cue type

	Cue Type Mean (SD)		
	One-unique	One-unique plus one-shared	Two-unique
Accuracy	.98 (.03)	.98 (.04)	.99 (.02)
Response Time (sec)	1.65 (.63)	2.00 (.82)	1.65 (.69)

Accuracy performance was at ceiling in all conditions. A repeated measures ANOVA [cue type: one-unique, one-unique plus one-shared (collapsed across distinctiveness levels[4]) and two-unique] on accuracy showed a non-significant effect of cue type: F (2, 130) =1.33, p>.05.

A repeated measures ANOVA [cue type: one-unique, one-unique plus one-shared (collapsed across distinctiveness levels) and two-unique] on response time showed a significant main effect of cue type: F (2, 130) = 64.41, p < .05, eta squared = .50. Pairwise comparisons showed that one-unique plus one-shared condition was significantly slower than one-unique condition and two-unique condition. There was no difference between one-unique and two-unique conditions (see Table 3.5). The above results support the memory-as-discrimination predictions; the increase in encoding-retrieval match by the addition of a

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[4] As will be seen below, no significant difference existed between these two condition either in accuracy or response time performance

shared cue impairs performance, whilst the addition of an extra unique cue makes no difference in response time performance.

Distinctiveness effect

We also tested whether there was a distinctiveness effect at test. This involved comparing the one-shared-standard condition to the one-shared-distinctive condition, as well as the one-unique plus one-shared-standard to one-unique plus one-shared-distinctive condition. This was done to determine if the presence of a distinctive cue at retrieval would provide a memory advantage in terms of accuracy or/and response time. We had to compare the two cueing conditions separately as both one-shared conditions had only three response buttons present instead of four that existed in the one-unique plus one-shared conditions.

Accuracy was at ceiling (see Table 3.6) which did not allow us to observe any effect. Accuracy for the shared-standard cue did not differ from accuracy for the shared-distinctive cue in either one-shared condition: $t\ (65) = -1.84$, $p>.05$, or in one-unique plus one-shared condition: $t\ (65) = .743$, $p>.05$. Paired T-Tests on response times showed a significant difference between the one-shared-standard and one-shared-distinctive cues: $t\ (65) = 2.21$, $p < .05$; one-shared-standard was significantly slower ($M = 2.26$, $SD = 1.14$) than one-shared-distinctive ($M = 2.05$, $SD = 1.05$). There was no difference between one-unique plus one-shared-standard and one-unique plus one-shared-distinctive: $t\ (65) = -0.17$, $p > .05$.

Table 3.6 Accuracy and response time results based on distinctiveness: one-shared-standard (1S), one-shared-distinctive (1Sd), one-unique plus one-shared-standard (1U1S) and one-unique plus one-shared-distinctive (1U1Sd)

	Cue Type Mean (SD)			
	1S	1Sd	1U1S	1U1Sd
Accuracy	.98 (.06)	.99 (.03)	.99 (.04)	.98 (.04)
Response Time (sec)	2.26 (1.14)	2.05 (1.05)	2.00 (.91)	2.01 (.84)

Exp.1 replicated previous results (Koutmeridou et al., 2011; Poirier et al., 2011) and supported memory-as-discrimination predictions. As suggested by Nairne (2002), increasing the encoding-retrieval match under the right circumstances can impair or have no effect on performance; when we consider the contrast between one-unique on the one hand and one-unique plus one-shared on the other, the increase in the match involved a reduction in the cues' capacity to discriminate between the candidates in the retrieval set. Consequently, the response time was slower for the one-unique plus one-shared condition despite the increase in encoding-retrieval match. In this case, increasing the match by adding a cue that was shared amongst two targets had no impact on accuracy and it was enough to significantly slow performance relative to a situation where a unique cue was presented on its own. Going from one-unique cue to two-unique cues, there was no increase in accuracy or any difference in the response times; the latter would have been expected from an encoding-retrieval match perspective due to the increase in match. Further support for memory-as-discrimination is provided by the comparison between one-unique plus one-shared and two-unique cues. In both cases, participants have to process two cues but one-unique plus one-shared condition was found to be significantly slower than two-unique.

The order of cue-shape selection within the drag-and-drop task seems to further support the memory-as-discrimination view, but also to support our predictions about cue processing; participants appear to favour the cues that have greater discriminative power. When a target required the selection of a shared-distinctive cue and two unique cues, participants did not favour the unique cue; they selected a unique cue first as often as they selected the shared-distinctive cue first. This was not true when a target required selection of a shared-standard cue and two unique cues. In this case, participants selected a unique cue first more frequently than a shared-standard cue.

Regarding distinctiveness, we only found supporting evidence for an effect in the one-shared condition where the presence of a shared-distinctive cue elicited faster responses. Concerning the one-unique plus one-shared condition both encoding and retrieval views predict that there will be a difference between the two conditions, albeit in a different direction; the encoding view predicts that one-unique plus one-shared-distinctive will be slower and the retrieval view predicts it will be faster. Contrary to both predictions, our results showed no significant difference between the two conditions. This absence of effect does not seem to be because the distinctive cue has no impact, since there was an effect in the one-shared condition.

One hypothesis that could explain this result is based on the behaviour observed within the drag-and-drop task. We discuss this here in some detail as the next two experiments aim to test the predictions of the said hypothesis; it turns out to be particularly relevant to our investigation of strategic cue processing.

As a reminder, in the drag-and-drop task, a target was shown, along with all possible cues in a randomly ordered row at the top of the screen (the order of the cues in the top row was randomised in every drag-and-drop trial). Participants were required to select the three cues that predicted the displayed target, in any order. The cue selection pattern in the drag-and-drop suggested that when a target was predicted by a shared-distinctive cue, participants chose it first in 48% of the trials. In contrast, when the target is related to a shared-standard cue then participants selected it first only in 28% of the trials (see Figure 3.4).

These differences in selection frequency led to a speculative hypothesis about processing time / processing priority of the cues in general, as follows. We assumed that, on average, processing favours one type of cue on a certain proportion of the trials. If this speculation is correct, then at test, on average, we would have different processing patterns depending on the combination of cues in each condition. If we extrapolate from the selection order in the drag-and-drop task, we would expect the more discriminative cues to receive more processing. In line with the drag-and-drop selection pattern, we would expect a unique cue to receive preferential processing when paired with the standard-shared cue in the one-unique plus one-shared-standard condition. In contrast, we would expect the shared-distinctive cue to receive as much processing as the unique one in the one-unique plus one-shared-distinctive condition.

This differential processing of the cues present at test could explain our failure to detect a distinctiveness effect in the two one-unique-plus-one-shared conditions. Let us assume, first, that there is a distinctiveness effect and that processing the shared-distinctive cue leads to a faster response (like the one observed in the one-shared condition). In that case, the one-unique plus one-shared-distinctive condition should also be faster than the one-unique plus one-shared-standard condition. Consider now the possibility that when presented with a one-unique plus one-shared-standard cue, participants preferentially process the unique cue rather than the shared-standard one (a processing pattern that is not present in the one-unique plus one-shared-distinctive condition). The priority processing of the unique cue, which uniquely identifies one target, may have resulted in faster response times than in the cases where the shared cue was equally processed. In effect, this type of processing may have given a response time advantage matching the advantage that the shared-distinctive cue provides in the other condition [See Figure 3.5 below for a graphical representation of this idea].

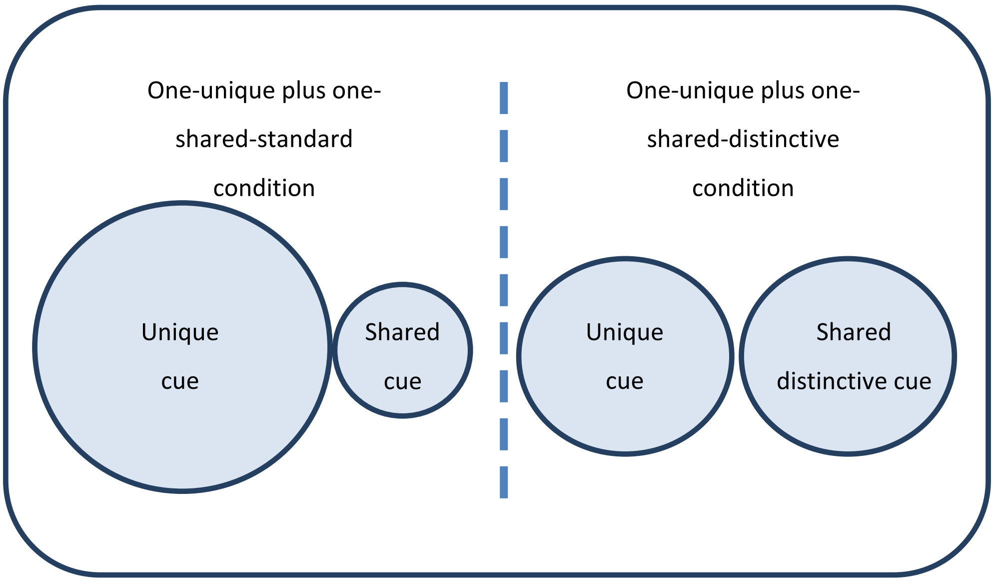

Figure 3.5 Graphical representation of the preferential cue processing hypothesis in the one-unique plus one-shared-standard versus the one-unique plus one-shared-distinctive conditions; it is assumed that this difference in cue processing in the two conditions equated the responses times.

The differential processing of the cues on the one hand and the distinctiveness advantage on the other hand may have balanced out the response times in the one-unique plus one-shared-standard condition and one-unique plus one-shared-distinctive condition. We hypothesised that if participants had processed the cues evenly in both one-unique plus one-shared conditions then we would observe a difference in the response times such that the cueing condition that involves the shared-distinctive cue would be advantaged.

In sum, Exp.4 results stress the importance of the diagnostic value a cue holds. We replicated the memory-as-discrimination results reported in the last experiment of Chap 2, providing evidence that the discriminative value that a cue holds is the best predictor of memory performance. Further support for this argument comes from the drag-and-drop task; the order each cue was selected seemed to be dependent on its discriminative power. The lack of distinctiveness effect in the one-unique-plus-one-shared conditions was speculated to be due to the differential cue processing patterns in each condition (distinctive and non-distinctive), which equated the observed response times. This *preferential cue processing hypothesis* was based on the cue selection patterns observed in the drag-and-drop task. Nevertheless, at this point, we have no empirical indication of what the actual cue processing patterns are. For this purpose in a follow-up study including the same material and procedure, we used an eye-tracker.

3.4. Experiment 5

Exp. 5 aimed to investigate cue processing patterns and to examine whether there is support for the *preferential cue processing hypothesis* described above. For this purpose, using exactly the same material, design and procedure as before, we measured eye movements to record the time allocated to each cue throughout the experiment.

The duration and the number of fixations on the cues were used as an index of processing priority. The prediction was that the time spent processing each type of cue, as well as the number of fixations, would depend on the discriminative value of the said cues. More specifically, we expected participants would spend more time and make more fixations on the unique cues than on any other cue type. The shared-distinctive cues were expected to come second and the shared-standard cues were thought to generate the smallest number of fixations and minimum fixation duration. We expected these predictions to hold true in all stages of the study (learning, training, and test). In addition, based on the speculative analysis described above, we predicted that the processing pattern in the one-unique plus one-shared-standard condition would be different to the one observed in the one-unique plus one-shared-distinctive condition: more processing of the unique than the shared-standard cue is expected in the former, while approximately even processing of both cues is anticipated in the second condition. If this differential processing prediction is supported, it is suggested that it may well have masked the distinctiveness effect in the previous experiment [in the one-unique plus one-shared conditions].

3.4.1. Method

3.4.1.1. Participants

A total of 24 unpaid participants (23 Female and 1 Male) with a mean age of 25 (SD=6) completed the task. They were recruited through the use of advertisements throughout the campus. The students were rewarded with a course credit, which could be redeemed in one of their psychology class.

3.4.1.2. Design and Materials

We used the same material and design as in Exp.4 along the SR Research Ltd. EyeLink II system to record eye-movements. The Eyelink uses a high sampling rate (500 Hz) and has two cameras adjusted underneath the participant’s eyes. An infrared sensor attached to the participant’s forehead allowed simultaneous detection of head position and head-motion compensation. In this study, we tracked the pupil (without corneal reflection) of the participant’s eye for which the most accurate calibration was achieved. Furthermore, stimulus displays were presented on two monitors connected by an Ethernet link. One of the computers was for the experimenter and the other one for the participant (21” ViewSonic monitor).

3.4.1.3. Procedure

The procedure was exactly the same as in Exp.4, except that eye-movements were recorded. Participants were tested individually within a session lasting approximately one hour. The researcher started the session by adjusting the headband on the participant’s head; then the calibration of the apparatus was initiated. The participant was asked to fixate a dot on the screen that was presented at nine different locations. The locations were always fixed but the order of their presentation was random across participants. The calibration was performed twice and the mean deviation between both measures had to be 1° or less for it to be considered successful. The experimenter was present in the room with the participant at all times. As in Exp. 4, there were three different phases: learning-training-test.

3.4.2. Results

Response strategy elimination check

Before running any other analyses, we wanted to confirm, once again, that the response bias uncovered in previous experiments (Exp.1 and Exp.2, Chapter 2) was eliminated. For this purpose, the targets pairs that shared a cue were identified (standard or distinctive) and the accuracy and response times associated to each member of the pair were compared both for the one shared and the one-unique-plus-one-shared conditions[5]. If the response bias was eliminated, then we should find no significant difference.

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[5] The two conditions had to be compared separately as the number of response buttons in each one differed (three buttons in the one-shared condition, four buttons in the one-unique plus one-shared condition

Repeated measures T-Tests showed no significant difference in accuracy between the two targets predicted by the standard one-shared cues: t (23) = .00, p>.05. The same was true for the one-shared-distinctive condition: t (23) = -1.45, p>.05. Repeated measures T-Tests showed the same pattern of result for response times [standard one-shared condition: t (23) = 1.54, p>.05; one-shared-distinctive condition: t (23) = 1.8, p>.05. Repeated measures T-Tests showed no significant difference between the two targets in the one-unique plus one-shared-standard condition in accuracy: t (23) = -1.81, p>.05. The same was true for the one-unique plus one-shared-distinctive condition: t (23) =.70, p>.05. Repeated measures T-Tests showed no significant difference between the two targets in the one-unique plus one-shared-standard condition in response time: t (23) = 1.9, p>.05. The same was true for the one-unique plus one-shared-distinctive condition: t (23) = .14, p>.05.

Participants responded as quickly and as accurately in all one-shared as well as one-unique plus one-shared conditions regardless the specific target tested (see Table 3.7). It seems that they did not favour a specific target when they encountered a shared cue. In other words, there was no evidence suggesting that participants used a response strategy like the one identified in previous experiments.

Table 3.7 Accuracy and response time (RT) for each target pair in one-unique and in one-unique plus one-shared conditions

	One-shared condition		One-unique plus one-shared condition	
	Accuracy	RT	Accuracy	RT
	Mean (sd)	Mean (sd)	Mean (sd)	Mean (sd)
Target 1 Pair A (shared-standard)	0.98 (0.05)	1.29 (0.34)	0.98 (0.04)	1.39 (0.33)
Target 2 Pair A (shared-standard)	1.00 (0.00)	1.17 (0.30)	1.00 (0.00)	1.39 (0.30)
Target 1 Pair B (shared-distinctive)	0.99 (0.04)	1.28 (0.42)	0.97 (0.07)	1.28 (0.42)
Target 2 Pair B (shared-distinctive)	1.00 (0.00)	1.16 (0.26)	1.00 (0.00)	1.16 (0.26)

Drag-and-drop results

Like in Exp.4, there were 3168 cue selections to be made across participants, 1056 per position. However, due to eye-tracker recording issues we only acquired data for 2322 selections across participants and 774 per position. Those issues are inherent to the tracking measures and are randomly distributed across participants and conditions. Response patterns for correct trials revealed that participants preferred certain cue types as their first selection (see Figure 3.6a and 3.6b for a detailed account of participants’ cue selection). The selection patterns of the shared-standard and shared-distinctive cues appear to follow opposite directions (see Figure 3.6).

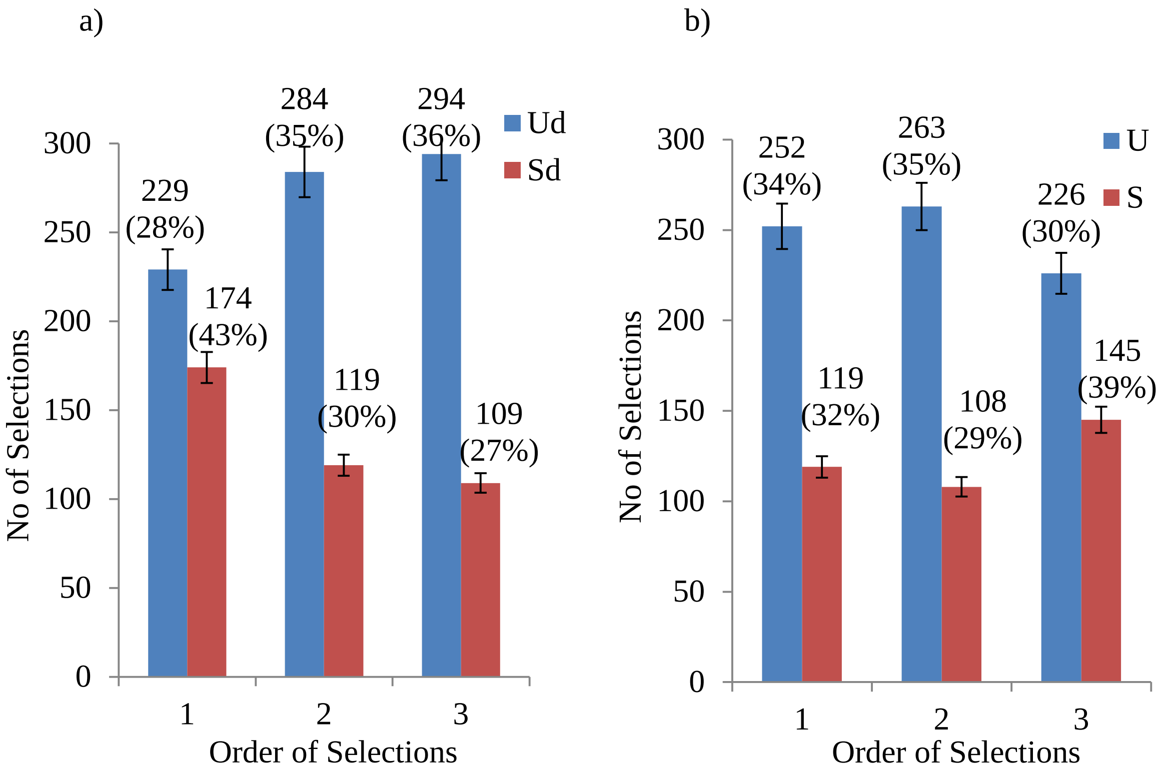

Figure 3.6 Average number of selections (and %) as a first, second or third choice for a) targets with a shared-distinctive (Sd) cue and b) targets with a shared-standard (S) cue.

The shared-standard cue was selected more often last than first or second, and the unique cue selected more often first or second rather than third (see Figure 3.6b). The shared-distinctive cue was selected first somewhat more frequently than second or last, and the unique mostly second or third than first (see Figure 3.6a). This trend, however, was not found to be significant. A 2 (distinctiveness: distinctive, non-distinctive) x 2 (cue type: unique, shared) x 3 (cue position: first, second, third) repeated measures ANOVA was performed. No significant interaction between cue type and position: F (2, 46) =.82, p=.45, nor among cue type, distinctiveness and position was found: F (2, 46) =1.95, p=.15.

Memory-as-discrimination analyses

All participants achieved high accuracy performance exceeding the 75% performance criterion in all conditions during the test phase. Response time for correct trials only was used and calculated in the same manner as in Exp.4 (see Table 3.8 for the average response time per condition across participants). The one-shared condition was not included in the memory-as-discrimination analyses as it included only three response buttons unlike the rest of the conditions.

Table 3.8 Accuracy and response time results based on cue type

	Cue Type Mean (SD)		
	One-unique	One-unique plus one-shared	Two-unique
Accuracy	.99 (.02)	.99 (.02)	1.00 (.01)
Response Time (sec)	1.05 (.15)	1.16 (.18)	1.03 (.15)

Accuracy data as a function of cue type collapsed across distinctiveness (cue type: one-unique, one-unique plus one-shared and two-unique) shows a ceiling effect. Consequently, a repeated measures ANOVA [cue type: one-unique, one-unique plus one-shared (collapsed across distinctiveness levels) and two-unique] on accuracy showed no significant difference: F (2, 46) = 1.25, p>.05. A repeated measures ANOVA [cue type: one-unique, one-unique plus one-shared (collapsed across distinctiveness levels) and two-unique] on response time showed a significant main effect of cue type: F (2, 46) = 25.91, eta squared = .53. Pairwise comparisons showed that one-unique plus one-shared condition was significantly slower than all other conditions as memory-as-discrimination predicts; an increase in encoding-retrieval match can lead to the reduction of performance if it is accompanied by an increase in cue overload. The two-unique condition was not significantly faster than the one-unique condition. In this case, the increase in encoding-retrieval match was not followed by an increase in performance, a result that is also in line with the memory-as-discrimination predictions.

Distinctiveness effect

We tested whether there was a difference between the two distinctiveness levels within the one-shared condition and the one-unique plus one-shared condition at test. Distinctiveness effects could not be observed in accuracy results as all conditions were close to ceiling (see Table 3.9). Paired T-Tests showed no accuracy difference in the one-shared condition: t (23) = -.81, p>.05, nor in the one-unique plus one-shared condition: t (23) = 1.00, p>.05. Mean response times were not significantly different either for the two distinctiveness conditions (see Table 3.9). Paired T-Tests showed no significant difference between standard one-shared and one-shared-distinctive: t (23) = -0.26, p > .05, or one-unique plus one-shared-standard and one-unique plus one-shared-distinctive: t (23) = -0.58, p > .05.

Table 3.9 Accuracy and response time results based on distinctiveness: one-shared-standard (1S), one-shared-distinctive (1Sd), one-unique plus one-shared-standard (1U1S) and one-unique plus one-shared-distinctive (1U1Sd)

	Cue Type Mean (SD)			
	1S	1Sd	1U1S	1U1Sd
Accuracy	.99 (.02)	.99 (.02)	.99 (.02)	.98 (03)
Response Time (sec)	1.07 (.18)	1.07 (.19)	1.16 (.21)	1.18 (.19)

Eye-movements analyses

Eye-movements were recorded through all three phases of the experiment (learning, both training tasks and test). Eye-movements were scored with the EyeLink Dataviewer, which superimposes the fixations on presented stimuli. Different measures were used as a function of the experimental phase, as detailed below.

Learning phase: All four targets and their related cues were presented one at a time for 10 seconds. Immediately after, a second, identical presentation followed. An analysis was conducted on the time spent in milliseconds (fixation duration) on the cues as a function of the presentation (first vs. second) and cue type (shared-standard, shared-distinctive, or unique). Participants spent more time fixating on the cues the first time that they were presented than the second time, and they spent more time on the shared-distinctive cue than the others (see Table 3.10). These results were confirmed by repeated-measures ANOVA. There was a main effect of cue type: F (2, 46) = 5.34, eta squared = .19, and of presentation order: F (1, 23) = 4.59, eta squared = .17, but the interaction was not significant: F (2, 46) =

0.65, p > .05. Participants' fixation durations were longer in the first presentation than the second. Post hoc comparisons (Tukey) revealed that participants spent more time looking at the shared-distinctive cue than the other two cue types (p<.05). The latter did not differ significantly.

Table 3.10 Fixation durations as a function of presentation order (first presentation, second presentation) and cue type (unique (U), shared-standard (S) and shared-distinctive (Sd).

	Fixation Duration (ms) Mean (SD)		
	Cues		
Presentation	Shared-standard	Shared-distinctive	Unique
First	2176 (714)	2654 (897)	2238 (365)
Second	1924 (848)	2576 (1032)	1976 (589)
Total	2050 (781)	2615 (964)	2106 (477)

A similar analysis based on the number of fixations on the cues as a function of the presentation order and their type was conducted. Participants fixated more on the cues the first time they were presented than the second time, and they fixated more often on the shared- distinctive cue than the others (see Table 3.11). These results were confirmed by repeated-measures ANOVA. There was a main effect of cue type: F (2, 46) = 4.49, eta squared = .19 and of presentation order: F (1, 23) = 5.00, eta squared = .18, but the interaction was not significant: F (2, 46) = 0.55, p > .05. Participants' number of fixations was higher in the first presentation than the second. Post hoc comparisons (Tukey) revealed that participants fixated more often on the shared-distinctive cue than the other two types of cue (p<.05). The latter did not differ significantly.

Table 3.11 Number of fixations as a function of presentation order (first presentation and second presentation) and cue type (unique (U), shared-standard (S) and shared-distinctive (Sd).

	Number of fixations Mean (SD)		
	Cues		
Presentation	Shared-standard	Shared-distinctive	Unique
First	5.96 (2.12)	7.55 (2.93)	6.22 (1.14)
Second	5.49(2.00)	7.01 (3.26)	5.30 (1.68)
Total	5.72 (2.06)	7.28 (3.10)	5.76 (1.41)

The above results suggest that the shared-distinctive cue draws more processing as shown by the significantly increased number and duration of fixations it received compared to the shared-standard or unique cues. This increased processing was sustained throughout the learning phase.

Drag-and-drop training task: An analysis was conducted on the time spent in milliseconds (fixation durations) and on the number of fixations on the cues as a function of their type (shared-standard, shared-distinctive and unique) (see Table 3.12). A repeated-measures ANOVA on fixation duration showed a main effect of cue type: F (2, 46) = 4.24, eta squared = .16. Post hoc comparisons (Tukey) revealed that participants spent more time looking at the unique cues than the shared-distinctive cue (p<.05). No other difference was significant. A repeated-measures ANOVA on the number of fixations did not reveal an effect of cue type: F (2, 46) = 2.82, p > .05.

Table 3.12 Fixation duration (msec) and number of fixations as a function of cue type

Mean (SD)

Measures	Shared-standard	Shared-distinctive	Unique
	Cues		
Fixation duration (msec)	789 (191)	734 (143)	827 (152)
Number of fixations	1.78(.45)	1.69(.43)	1.90(.33)

Test phase: Analyses were conducted on the time spent (fixation duration in milliseconds) and the number of fixations on the cues as a function of test condition and cue types (see Table 3.13). We looked separately at the one-unique plus one-shared-standard condition and the one-unique plus one-shared-distinctive condition to explore the gaze patterns for each cue within each condition. Our preferential cue processing hypothesis predicted that there would be no difference in processing time allocated to the unique compared to the shared-distinctive cue in the one-unique plus one-shared-distinctive condition. Conversely, a difference was expected in cue processing patterns in the one-unique plus one-shared-standard condition with the unique cue attracting more processing than the shared-standard cue.

In the one-unique plus one-shared-standard condition, participants fixated more often on the unique cue than on the shared-standard cue: t (23)=-2.31, p<.05 (see Figure 3.13), but there was no difference in the overall fixation duration between the two cues: t (23) = -1.13, p > .05. In the one-unique plus one-shared-distinctive condition, there was no significant difference either in fixation duration: t (23) = -.24, p > .05), or number of fixations: t (23) = -.48, p > .05 between the two cue types.

Table 3.13 Fixation duration (msec) and number of fixations as a function of distinctiveness and cue type

Mean(SD)				
Conditions				
	one-unique plus one-shared-standard condition		one-unique plus one-shared-distinctive	
Measures	Unique	Shared-Standard	Unique	Shared-Distinctive
Fixation duration (ms)	406.12 (156)	373.77 (104)	387.94 (150)	382.93 (156)
Number of fixations	1.57 (.43)	1.34 (.40)	1.43 (.37)	1.39 (.45)

In sum, Exp.5 showed that there was no distinctiveness effect in any of the testing conditions (one-shared, one-unique plus one-shared) failing to replicate our previous result in the one-shared condition. In terms of cue processing, in the drag-and-drop task a cue selection trend was observed that was in line with Exp.4 results. However, this trend was not significant. This may well be due to the substantial loss of data. Either way, since we can't reach clear conclusions relatively to the cue selection order, further exploration is needed.

Eye-tracking results showed that, during learning, participants fixated on the shared-distinctive cue more often and for a longer time than the unique or the shared-standard cue. In the drag-and-drop task fixation duration was significantly longer for the unique cues compared to the other two cue types. In the cued-recognition task, participants made more fixations on the unique cues than the shared-standard when presented with the one-unique plus one-shared-standard condition. There was no such difference in the one-unique plus one-shared-distinctive condition. Assuming fixations are correlated with processing, participants do not process the shared-standard cue as much as the shared-distinctive cue. Our eye-tracking findings during test suggest that differential processing took place based on the cue type and that the presence of a shared-distinctive cue altered the processing pattern (see Table 3.13); the shared-distinctive cue seems to attract as much processing as the unique cue in the one-unique plus one-shared-distinctive condition. In contrast, the unique cue seems to attract more processing in terms of number of fixations than the shared-standard cue in the one-unique plus one-shared-standard condition. As explained before, this may have been why there was no response time advantage for the distinctive condition. If the amount of processing that both types of shared cues receive can be equated, then it follows a difference between the two conditions should emerge.

3.5. Experiment 6

In this study our goal was to test whether the distinctiveness effect was previously masked by different patterns of cue processing in the one-unique plus one-shared conditions. Assuming this was the case, the effect should be uncovered if the same processing pattern was applied in both conditions. To achieve this, the cue presentation order during test was modified. More specifically, in the testing conditions where there was a shared cue (standard or distinctive), the said shared cue was always presented first, in isolation, for a fixed period of time. It was thought this would encourage participants to spend the same amount time processing the two different shared cues before the unique cue is presented [in the one-unique condition, a filled square replaced the shared cue]. Based on Exp.4 results where the one-shared-distinctive condition was found to be faster, we predicted that target selection would be more efficient in the one-unique plus one-shared-distinctive condition than in the one-unique plus one-shared-standard condition. In addition, since we used the same material and design, Exp. 6 will enable us to verify if the cue selection order observed in Exp. 4 (but not Exp. 5) during the drag-and-drop task is reliable.

3.5.1. Method

3.5.1.1. Participants

Thirty-three City University students (12 Male and 21 Female) with a mean age of 25 (SD=9) took part in this study. They responded to advertisements posted through City University London systems and were rewarded with either one course credit or £5 for their participation.

3.5.1.2. Design and Materials

The material and design were exactly the same as in Exp.4 and 5 with the exception of a slight change in the test phase that is described below.

3.5.1.3. Procedure

The learning and drag-and-drop phases were kept the same as before. The only change was in the cued-recognition training and test phase. Previously, all relevant cues and potential targets were presented simultaneously. Here, we introduced a 0.5 sec time lapse between the presentation of the first cue and of subsequent ones; first, participants were presented with a warning signal for 500 ms; the first cue was then presented. If the condition tested involved a shared cue (either standard or distinctive) –one-shared and one-unique plus one-shared – this was always presented first; after another 500 ms, the second cue was presented along with the response buttons. In the two-unique condition, after the warning signal, the first unique appeared on its own and then the second one along with the response buttons. In the cases where only one unique cue was presented, the unique cue appeared first followed by a small black square and the response buttons. Participants were instructed to use the first cue that appeared on screen and try and link it to correct targets, rather than wait for all cues to appear.

3.5.2. Results

Response strategy elimination check

Once again, we first examined whether the response bias was eliminated. We identified the target pairs that shared a cue (standard or distinctive). Then, we tested whether accuracy or response time was different for one of the two targets in the one shared and in the one-unique plus one-shared conditions. If the response bias was eliminated, then we should find no significant difference.

Repeated measures T-Tests showed no significant difference between the two targets in the one-shared-standard condition either in accuracy: $t(32) = -.44$, $p>.05$, or response time: $t(32) =-.80$, $p>.05$. The same was true for the one-shared-distinctive condition: paired t-test for accuracy: $t(32) =-.57$, $p>.05$ and for response time: $t(32) =1.65$, $p>.05$. Repeated measures T-Tests showed no significant difference between the two targets in the one-unique plus one-shared-standard condition in accuracy: $t(32) =-1.00$, $p>.05$, or response time: $t(32) =.378$, $p>.05$. The same was true for the one-unique plus one-shared-distinctive condition: paired t-test for accuracy: $t(32) =-.57$, $p>.05$ and for response time: $t(32) = 1.75$, $p>.05$.

Participants responded as accurately and as quickly in all one-shared as well as one-unique plus one-shared conditions regardless the specific target tested (see Table 3.14). It seems that they did not favour a specific target when they encountered a shared cue; hence, there is no evidence that a response strategy was called upon.

Table 3.14 Number and response time (RT) for each target pair in one-unique and in one-unique plus one-shared conditions

	One-shared condition		One-unique plus one-shared condition	
	Accuracy	RT	Accuracy	RT
	Mean (sd)	Mean (sd)	Mean (sd)	Mean (sd)
Target 1 Pair A (shared-standard)	0.99 (0.04)	1.27 (0.59)	1.00 (0.02)	1.00 (0.43)
Target 2 Pair A (shared-standard)	0.99 (0.03)	1.32 (0.54)	1.00 (0.00)	0.98 (0.34)
Target 1 Pair B (shared-distinctive)	0.99 (0.03)	1.26 (0.51)	0.99 (0.04)	0.95 (0.33)
Target 2 Pair B (shared-distinctive)	1.00 (0.02)	1.16 (0.42)	0.99 (0.03)	0.87 (0.24)

Drag-and-drop results

Each participant had to make 12 cue selections in each position. Overall, there were 1584 selections made across participants; 528 selections for each of the three positions. Selection order pattern replicated the findings of Exp.4: the shared-standard cue was mostly selected last, while the shared-distinctive cue was mostly selected first (see Figure 3.7).

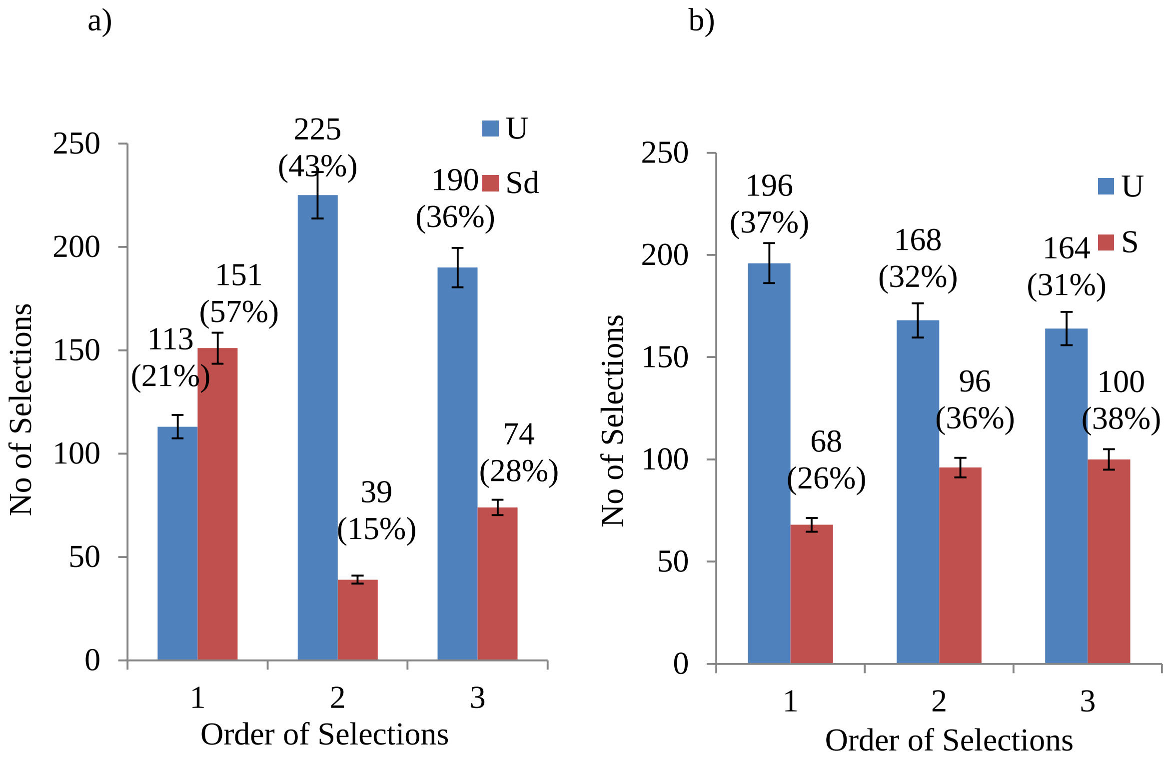

Figure 3.7 Average number of selections (and %) as a first, second or third choice for the shared-standard, unique and shared-distinctive cues for a) targets with a shared-distinctive cue b) targets a shared-standard cue

A 2 (distinctiveness: distinctive, non-distinctive) x 2 (cue type) x 3 (cue position: first, second, third) repeated measures ANOVA was performed on selections for each position per participant [note: there were 12 selections for each position per participant]. A three-way significant interaction was found among cue type, distinctiveness and position: F (2, 64) = 11.04, p<.001, eta squared=.26. Simple main effects analyses showed different selection patterns based on cue type and distinctiveness. For targets with a shared-distinctive cue (see Figure 3.7a), there was a significant order selection pattern based on cue type: F (2, 64) = 9.75, p<.001, eta squared = .23; the unique cues were selected significantly less in the first position (M=3.42, sd = 3.3) than the third (M=5.76, sd=2.51). There was a marginal difference (p=.053) between the third position and the second (M=6.82, sd=1.88). The shared-distinctive cues were selected significantly more in the first position (M=4.58, sd=3.25) than the second (M=1.18, sd=1.88) or third (M=2.24, sd=2.51). There was a marginally significant difference (p=.051) between the latter two. There was no significant selection pattern for targets with a shared-standard cue (see Figure 3.7b): F (2, 64) = 1.13, p>.05.

We also run paired T-Tests comparing the unique and shared cues selected per position. In the first position, participants selected significantly more unique (M=5.94, sd=2.40) than shared-standard cues (M=2.06, sd=2.40): t (32) =4.65, p<.001 but there was no such difference between the unique (M=3.42, sd=3.25) and the shared-distinctive cues (M=4.58, sd=3.25): t (32) =-1.02, p>.05. In the second position, participants selected significantly more unique (M=5.09, sd=2.31) than shared-standard cues (M=2.91, sd=2.31): t (32) =2.713, p<.05 and more unique (M=6.82, sd=1.88) than shared-distinctive cues (M=1.18, sd=1.88): t (32) =8.62, p<.001. In the third position, participants selected significantly more unique (M=4.97, sd=2.28) than shared-standard cues (M=3.03, sd=2.28): t (32) =2.44, p<.05 and more unique (M=5.76, sd=2.51) than shared-distinctive cues (M=2.24, sd=2.51): t (32) =4.02, p<.001.

The selection patterns of the shared-standard and shared-distinctive cue appear to follow opposite directions (see Figure 3.7). It appears that the nature of the cue and the information it provides relative to the target may play a role in the order in which they were selected. More specifically, it seems that the cues that are more discriminative (unique or shared-distinctive) were preferably placed in the first positions. This is particularly clear if we consider the lack of significant difference between the shared-distinctive cue and the unique cue in the first position, while there is one between the shared-standard and the unique.

Memory-as-discrimination analyses

All participants achieved high accuracy performance exceeding the 75% performance criterion in all conditions during the test phase. Response time for correct trials only was used and calculated in the same manner as in Exp.4 and 5 (see Table 3.15 for the average response time per condition across participants). The one-shared condition was not included in the memory-as-discrimination analyses as it included only three response buttons unlike the rest of the conditions.

Table 3.15 Accuracy and response time results based on cue type

	Cue Type Mean (SD)		
	One-unique	One-unique plus one-shared	Two-unique
Accuracy	.99 (.02)	.99 (.02)	1.00 (.01)
Response Time (sec)	0.80 (.21)	0.85 (.25)	0.74 (.14)

A repeated measures ANOVA [cue type: one-unique, one-unique plus one-shared (collapsed across distinctiveness levels) and two-unique] on accuracy showed a non-significant effect: F (2, 64) =2.44, p>.05. A repeated measures ANOVA [cue type: one-unique, one-unique plus one-shared (collapsed across distinctiveness levels) and two-unique] on response time showed a significant main effect of cue type: F (2, 64) =13.38, p<.001, eta squared = .298). Pairwise comparisons revealed that one-unique plus one-shared condition was significantly slower (M=.85, sd=.25) than the one-unique condition (M=.80, sd=.21) and the two-unique condition (M=.74, sd=.14). The one-unique condition was significantly slower than the two-unique condition. Results replicated previous studies with one-unique plus one-shared condition being significantly slower than the other two. The decrease in discriminative power that accompanied the increase in encoding-retrieval match hurt performance.

Distinctiveness effect analyses

Distinctiveness effects could not be observed in accuracy results as all conditions were at ceiling (see Table 3.16). Our hypothesis was that the distinctive conditions would be faster than the non-distinctive based on Exp.4 results. Response times were calculated as in Exp.4 (see Table 3.16 for response times in each condition).

Table 3.16 Accuracy and response time results based on distinctiveness: one-shared-standard (1S), one-shared-distinctive (1Sd), one-unique plus one-shared-standard (1U1S) and one-unique plus one-shared-distinctive (1U1Sd)

	Cue Type Mean (SD)			
	1S	1Sd	1U1S	1U1Sd
Accuracy	.99 (.02)	.99 (.02)	1.00 (.01)	.99 (03)
Response Time (sec)	1.24 (.57)	1.11 (.43)	.89 (.29)	.81 (.22)

A priori contrasts (paired-sample T-tests) showed a significant difference between one-shared-standard and one-shared-distinctive conditions replicating Exp.4 result: t (32) = 2.67, p<.05. One-shared-standard (M=1.24, sd=.57) was significantly slower than one-shared-distinctive (M=1.11, sd=.43). There was also a significant difference between one-unique plus one-shared-standard and one-unique plus one-shared-distinctive: t (32) = 2.01, p<.05. One-unique plus one-shared-standard (M=.89, SD=.29) was significantly slower than one-unique and one-shared-distinctive (M=.81, SD=.22). The distinctive condition was found to be significantly faster in both cases. It appears that our cue presentation manipulation revealed the distinctiveness effect in the one-unique plus one-shared condition as well.

3.6. General Discussion

The main goal was to examine whether the discriminative value of cues affects their processing. An additional goal was to test memory-as-discrimination’s most counter-intuitive prediction: under the right circumstances increasing the encoding-retrieval match can hurt performance. We conducted three experiments using a cued-recognition task; each of four non-words (targets) were associated with two shapes (cues) that differed in discrimination power (unique cue, shared-standard cue or shared-distinctive cue). These variations in cue types were introduced to establish whether the diagnostic value of the retrieval cues is what affects performance. The use of unique, shared-standard and shared-distinctive cues would also help us observe the dynamics of cue processing and whether the more diagnostic cues are favoured in terms of processing.

According to the distinctiveness literature, a distinctive cue is thought to be more diagnostic of the target. Nairne stresses that distinctiveness is best to be considered as a property of a cue in context and what determines performance is the overlap between the features of the target item and those of the background items (Nairne, 2002; 2006). Hunt and Smith (1996) argued that processing item differences in a context of similarity (distinctive processing) is highly diagnostic of a particular item. In addition, Koutmeridou et al., (2011) results demonstrated that a distinctive cue altered the subjective organisation of the learning material and the cue processing dynamics in an obvious manner. Thus, including a distinctive cue would help us observe the processing patterns based on the discriminative power of the cues.

Regarding the memory-as-discrimination predictions, response time results from all three experiments reported here replicated previous findings (Poirier et al., 2011) and supported the memory-as-discrimination view; increasing the encoding-retrieval match can have no effect (e.g. no response time difference when going from one-unique to two-unique in Exp.4 and 5), improve performance (e.g. in Exp.6, two-unique condition was faster than one-unique) or, impair performance (e.g. one-unique was faster than one-unique plus one-shared in all experiments) (Nairne, 2002). The addition of a retrieval cue that also decreased discrimination power significantly slowed response time performance. Moreover, the addition of another unique cue did not always increase performance, as it would have been expected within an encoding-retrieval match framework and, in all likelihood, the memory as discrimination perspective. The comparison between one-unique plus one-shared and two-unique cues confirms that the above results are not due to the different number of cues in each condition; in both cases participants had to process two cues but still one-unique plus one-shared condition was found to be significantly slower than two-unique. Thus, the encoding-retrieval match is not sufficient to explain memory performance as the predictions it generates cannot be trusted. Successful retrieval performance does not depend on the match of encoding and retrieval conditions, but rather on a diagnostic retrieval mechanism - the degree to which retrieval conditions uniquely specify one target to the exclusion of others (Nairne, 2001; Nairne, 2002; Surprenant & Neath, 2009).

The order of cue selection within the drag-and-drop task seems to further support the memory-as-discrimination view; participants favour the cue whose discriminative power is superior [or is made superior by selective processing of cue-target relationships]. Taken together, results from the three experiments suggest that the diagnostic value of each cue determined whether it was selected first, second or last. Unique cues were mostly selected first or second rather than last. Shared-standard cues and shared-distinctive cues have opposite selection order patterns; shared-standard cues are preferably selected last, while shared-distinctive cues are more often selected first. In Exp.6, there was no difference in the number of times participants selected a unique cue relative to a shared-distinctive cue in the first position, while a shared-standard cue was significantly selected less than a unique cue in that position.

Let us now consider the distinctiveness results in light of cue processing. In the cued-recognition task, participants were presented with one or two shapes (cues) along with four response buttons [note: three response buttons were present in the one-shared condition], each for one target, and they had to click on the correct target as quickly as possible. The distinctiveness literature (briefly reviewed in the introduction) suggests that a distinctive cue provides an advantage at the point of retrieval. Thus, in the cued-recognition task, we were expecting to observe a distinctiveness advantage in both the relevant cueing conditions (one-shared-standard versus one-shared-distinctive and one-unique plus one-shared-standard versus one-unique plus one-shared-distinctive). Exp.4 yielded inconclusive results; there was a significant response time advantage for the distinctive cue in the one-shared conditions but no difference was found in the one-unique plus one-shared between the standard and distinctive conditions. As explained in the discussion of Exp.4, we hypothesised that this may have been due to the differential processing of the two cues in those conditions (see Figure 3.5). Taken together, Exp.5 eye-tracking results provide some support for this hypothesis; cue processing priority appears to be guided by the discriminative value of the cue type – if a cue carries more information in terms of discriminating between retrieval candidates (i.e. unique, shared-distinctive) – then it tends to be processed and fixated more. A critical finding supporting this hypothesis was the preferential processing of the cues in the one-unique plus one-shared-standard condition at test; participants made significantly more and longer fixations on the unique cue than on the shared-standard one. Interestingly, this was not found in the one-unique plus one-shared-distinctive condition; the amount and duration of fixations did not differ between the unique and the shared-distinctive cue. It appears that the shared-distinctive cue attracts as much processing as the unique one. This behaviour is thought to be adaptive as it reduces the discrimination problem posed by several of the conditions studied here. By favouring certain cues over others (i.e. the unique in the one-unique plus one-shared-standard condition), performance is enhanced compared to what it would have been if all cues were evenly processed.

Manipulating (to an extent) at test the processing time allocated to each cue by always introducing the shared cue before the unique (Exp.6), eradicated this advantage and revealed the distinctiveness effect. The conditions including a distinctive-shared cue led to faster response times. This was observed in both the one-shared and one-unique plus one-shared conditions. Encoding-retrieval match would not predict this effect as both conditions share the same match between encoding and retrieval. In principle, the results are in agreement with memory-as-discrimination theory - it is the discriminative value of each cue that matters the most. Faster responses to the shared-distinctive cue relative to the standard-shared as well as to the one-unique plus one-shared-distinctive relative to the one-unique plus one-shared-standard can only be attributed to the increased discriminative power of the distinctive cue. However, as mentioned in the introduction, the observed effect cannot be predicted with the simplified retrieval model presented by Nairne (2002) for two reasons; firstly, it is not intended for response time results and secondly, it cannot account for shared cues taking on different weights through experience. Our findings complement Koutmeridou et al.'s (2011) results and clearly show that shared cues are not necessarily treated in the same manner; some attract more processing than others (i.e. shared-distinctive versus shared-standard). Incorporating this differential processing into the original memory-as-discrimination view could allow for more accurate predictions.

In relation to the above points, there is the issue of functional cue formation. Within the literature on cue effectiveness and cue selection, there is no clear consensus as to what drives functional cue selection, processing and elaboration (e.g. meaningfulness, Solso, 1968; formal similarity, Cohen and Musgrave, 1966). Which features of the nominal cue are chosen for the composition of the functional cue? What are the factors that drive the conversion of a potentially effective nominal cue into an actually effective functional one [or not]? In Koutmeridou et al. (2011), participants actively processed the nominal cues in such a way that their discrimination values changed. By adopting a response strategy and by partially suppressing the relationships between some of the cues and targets, participants reduced the interference caused by the shared cue, increasing the shared cue's discrimination power. Our results suggest that an important determinant of cue processing, effectiveness, and cue selection, is discrimination power. The latter may well be one of the guiding forces of cue transformation from nominal to functional. A hypothesis is that the more discriminative a cue is, the more processing it will receive and, chances are, that it will be transformed to a functional cue. The findings reported in this paper suggest that the discrimination power a cue holds could be manifested in different ways (e.g. meaningfulness, formal similarity, distinctiveness), but no matter the type of manifestation, the cue with the greater discrimination power is more likely to be given processing priority, or/and chosen as the functional cue. In case this is true, every day information processing could, in many situations, be guided by the information value of the given stimuli. Evidently, what is reported here cannot lead to a conclusive answer and further investigation is needed. Nonetheless, we would argue that we provide sufficient data in support of this hypothesis for it to be considered further. Future research needs to explore how much the task-related goals determine cue processing biases, and how significant such a bias is in everyday functioning.

Chapter 4:

General Discussion

4.1. Thesis rationale and goals

The underlying theme of this thesis was related to the active processing of information based on task goals and discriminative value, and how this affects the allocation of processing, the transformation of nominal cues and, ultimately, memory performance. This theme is expressed as two aims relating to three separate areas; memory-as-discrimination, encoding strategies/processing and distinctiveness effects.

The first goal was to thoroughly examine the confounding effect that cue processing biases may have had in previous studies testing memory-as-discrimination predictions (i.e. Poirier et al., 2012). Nairne (2001; 2002) challenged the principle of encoding-retrieval match and proposed that it is not the match per se that determines performance, but the extent to which a cue uniquely identifies a target to the exclusion of others. The implication of this is clear; the level of cue to target similarity (the encoding-retrieval match) is not predictive of memory performance. Previous studies have demonstrated that encoding-retrieval match may have a beneficial, a null, or a detrimental effect on retrieval performance (e.g. Poirier et al, 2012). This suggests that there is no causal relationship between encoding-retrieval match and retrieval performance. However, these findings could have been the result of specific cue processing biases. This thesis investigated the effect of those biases on performance and re-evaluated the memory-as-discrimination findings after addressing them.

A second goal was to investigate the role of the diagnostic value of the memory cues in the implementation of encoding strategies and the allocation of processing. It is well established that people actively process learning material converting the nominal cues into functional ones (e.g. Tulving and Patterson, 1968; Tulving and Thompson, 1973). In the course of this thesis, we examined a memory-as-discrimination hypothesis that suggests that, what guides the transformation of the nominal cues into functional ones is the perceived discrimination power of the cues. According to this view, providing task characteristics allow it, participants will favour the more diagnostic cues and employ encoding strategies that minimise the interference associated with less discriminative cues. The notion of distinctive processing – the processing of stimulus differences in the context of similarities (Hunt, 2003) – seems to support this view as targets that received such processing appear to have an advantage.

4.2. Review of empirical work and theoretical implications

Memory-as-discrimination revisited

The prediction that increasing the encoding-retrieval match can lead to a decrease in performance is the critical prediction of the memory-as-discrimination view. Poirier et al (2011) made it possible to manipulate both encoding-retrieval match and cue overload orthogonally with the use of a cued-recognition task. Participants were asked to associate four consonant-vowel-consonant (CVC), non-word targets with sets of three shapes each. Two of the shapes were unique to a target while the remaining shape was shared between two targets. Participants learned these associations within a learning phase, until performance was above 75% correct. 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 target that had been associated with that set of shapes. The predictions made by the encoding-retrieval match and the memory-as-discrimination view contrast each other in relation to one-unique plus one-shared condition; performance is expected to be superior in that condition from an encoding-retrieval match perspective, whereas it is expected to be impaired from a memory-as-discrimination angle. Poirier et al (2011) provided evidence for this counter-intuitive prediction.

However, their findings are open to alternative interpretations that relate to the methodology they used. The worse performance in the one-unique plus one-shared condition, relative to the one-unique condition, could be observed for reasons that are not due to the decreased discrimination power in that condition. In their task, the shared cue's position was randomly determined, implying that on approximately 50% of the trials it appeared first while for the remaining 50% of the trials, the unique cue appeared first. We hypothesised that responding would take more time when the shared cue appeared first than when the first cue on the left was unique. This would result in one-unique plus one-shared condition being, on average, slower only because of the order in which the cues were processed in that condition at test (shared cue or unique cue first). Exp.1 and 2 of Chapter 1 used the same cued-recognition task as in Poirier et al. (2011) and tested the hypothesis that at test, participants interrupt processing as soon as they have encountered a unique cue. Exp.1 and 2 found no support for this alternative interpretation. The processing order of the cues had no effect on response time in the one-unique plus one-shared condition; trials where the shared cue appeared first were undistinguishable from the trials were the unique cue appeared first. It seems that participants do not ignore the shared cue in the one-unique plus one-shared condition but they base their response on both cues.

Further analyses of the response protocols, however, indicated that a response bias was confounding the results providing a second alternative interpretation. The fact that the one-unique plus one-shared condition was slower appears to have been due to a processing bias whereby most participants (70% and 75% in Exp.1 and 2 respectively) preferentially associated the shared cue with one of the two possible targets. In the one-shared condition, at test, participants focused, most of the times, on just one correct target response. This bias created two sets of targets; the favoured targets, which the shared cue came to predict, and the non-favoured targets that were rarely selected as a response to the shared cue – albeit a correct one just like the favoured targets. In the one-unique plus one-shared condition, the shared cue could be presented along with a unique cue that defined a favoured target as the correct response, or with a unique cue that defined a non-favoured target. As a consequence of the described bias, performance could have been compromised in the latter case; the unique cue points unequivocally towards the non-favoured target while the shared cue points in the direction of the favoured target. The resulting conflict can lead to slower response times on these trials. This interpretation was supported by our findings in both Exp.1 and 2; although overall there was a slower response for the one-unique and one-shared condition, this was not the case when only the favoured targets were considered—the targets that were consistently selected when the shared cue was presented on its own. For these targets there was no significant effect of cue type, unlike what either encoding-retrieval match or memory-as-discrimination would predict. For the non-favoured targets, the one-unique plus one-shared condition was significantly slower and less accurate than the one-unique condition. Favoured targets were found to lead to more accurate and faster performance in the one-unique plus one-shared condition than the non-favoured targets. Taken together, Exp.1 and 2, clearly suggest that it is the response strategy, rather than the reduced discrimination power of the cues, that was responsible for the difference reported between the one-unique plus one-shared and the one-unique condition.

In order to test the memory-as-discrimination argument, the elimination of this response strategy was necessary. Participants needed to process the shared cues as predicting both the targets they were associated with. Exp.3 of Chapter 2 addressed this issue and allowed for the elimination of the strategy by altering two aspects of the cued-recognition task. The first was the inclusion of a drag-and-drop training task; participants were presented with one target at a time and all the cue-shapes and they had to drag-and-drop the corresponding shapes into three response boxes. The second alteration lied in the one-shared condition; we presented participants with only three response buttons (instead of all four) including only one of the correct targets each time. Participants had to reach the performance criterion separately for each one of these targets. The changes we implemented appeared to have eliminated the response strategy. If participants were still biased in this paradigm, they would have been more accurate and/or faster in the one-shared condition and in the one-unique and one-shared condition for just one of the two targets associated with the shared cue. However, participants responded as accurately and as quickly in all one-shared and in all one-unique plus one-shared conditions regardless the specific target tested. It seems that they did not favour a specific target when they encountered a shared cue. This altered version of the cued-recognition task was also employed in the three studies described in Chapter 3 to ensure the elimination of the observed response bias.

Exp.3 of Chapter 2, as well as all three experiments of Chapter 3 found evidence in favour of the memory-as-discrimination view. None of the experiments (that controlled for the response strategy) in which encoding-retrieval match and cue overload were orthogonally manipulated showed a significant effect of encoding-retrieval match independent of cue overload. When the increase in match did not alter cue overload (e.g. going from one-unique to two-unique), there was no difference in accuracy, while there was just one case where the two-unique condition was faster than the one-unique (Exp.6, Chapter 3). When the increase in match also involved a subsequent increase in cue overload (e.g. going from one-unique to one-unique plus one-shared) response time was slower for the less discriminative condition (i.e. one-unique and one-shared), while there was no difference in accuracy. The comparison between one-unique plus one-shared and two-unique cues confirms that the above results are not due to the different number of cues in each condition; in both cases participants had to process two cues but still one-unique plus one-shared condition was found to be significantly slower than two-unique.

Our findings, as well as those of Poirier et al. (2011) and Goh & Lu (2012), suggest that the capacity of a cue to discriminate between potential targets should be considered as the only predictor of performance. It was shown that less information was more effective when it was more diagnostic of the retrieval target (and that a better match can be less effective). As stressed by Nairne (2001, 2002, 2005, 2006), an increase in the encoding-retrieval match can have no effect, can support retrieval or hinder performance depending on the relationship between that increase, the target and the competing retrieval candidates. It appears that encoding-retrieval match is not related to performance as was previously suggested (e.g. Tulving, 1984 but see Nairne, 2002 and Surprenant & Neath, 2009); the predictions it generates cannot be trusted, hence, it does not seem to be a valid explanation of memory performance. Successful retrieval performance does not depend on the extent of the match between encoding and retrieval information, but rather on a diagnostic retrieval mechanism (the degree to which retrieval conditions uniquely specify one target to the exclusion of others) (Nairne, 2001; Nairne, 2002; Surprenant & Neath, 2009). However, in most cases, increasing the match will lead to a more diagnostic cue constellation and thus better performance.

Cue processing and the construction of functional cues: a memory-as-discrimination perspective

In the course of this thesis, we explored how the diagnostic value of each cue affected their processing, their effectiveness and their potential selection as functional cues. Taken together, Exp.1 and 2 (Chapter 2) showed that, when faced with a cue that is associated with two targets, participants appear to go to some length to reduce the potential negative impact of the loss in discriminative power the shared status of the cue implies. More specifically, a large majority of individuals (around 70%) chose to adopt a strategy that, ultimately, transformed the overloaded cue into a cue that is *mostly* associated with one of the targets and less associated with the alternative target. If one considers that cue overload reduces the value of a cue in terms of retrieving a target, then our findings suggest that people spontaneously choose to favour some relationships in order to preserve the predictive value of a cue. This involved favouring one of the cue-target relationships and suppressing the other. It appears that, in Exp.1 and 2 (Chapter 2), the discriminative value of each cue determined the way in which it was processed, leading to the development of the identified response strategy; the differential processing of the relationship between the shared cue and each of the two targets it initially predicted, in effect turned the shared nominal cue into a (somewhat) unique functional cue. When considered in detail, the findings summarised above suggest that participants actively attempt to maximise discriminative power if the experimental set-up allows them to do so. By adopting an encoding strategy, participants reduced the response competition caused by the shared cue in at least 50% of the test trials. Hence, the strategic processing of the cues appeared to be an effort to transform shared cues into more discriminative functional quasi-unique cues.

The findings of this series also showed that the favoured association could be experimentally controlled or induced by the presence or absence of distinctive unique cues (Exp.2 of Chapter 2). In our experiment, when available, the unique distinctive cue was selected as the main functional cue for that target. The shared cue for that target was preferentially associated with the alternative target that did not contain a unique distinctive cue. The participants actively processed the nominal cues in such a way that their nominal values changed and the presence of a distinctive cue provided a certain direction for that processing. The above findings support Underwood et al. (1962) since participants seem to have chosen part of the initial complex cue to be the effective retrieval cue and, as Runquist (1971; 1973b; 1974a; 1975) had suggested, in case a distinctive cue is present, it is preferred. The implication of the above is that every day information processing could, in many situations, be guided by the information value of a given stimulus and may result to an aversion towards cues that do not help solve the discrimination problem involved in retrieval.

Exp.3 (Chapter 2) implemented a procedure that ensured the elimination of the observed response strategy (in order to achieve the first goal of the thesis). An interesting observation was that, even after the elimination of the response bias, the participants, given the chance, favoured the more discriminative cues. This was evident when we examined the order in which the cues were selected during the drag-and-drop practice task. Participants were required to drag-and-drop the cue/shapes that corresponded to the target shown into three response boxes—in any order. Response patterns revealed that participants preferred to select certain types of cues first. In line with the memory-as-discrimination view, it appears that the nature of the cue and the information it holds for the target played a role: the cues that were more discriminative (unique) were selected first.

The use of a distinctive (shared) cue in the experiments reported in Chapter 3 were mainly regarded as tools to manipulate and reveal more clearly people's processing patterns. However, their presence created an opportunity to, also, test the distinctiveness effect. Nairne (2006) regards distinctiveness as a property of a cue in context and favours a combination of retrieval and encoding processes. Encoding provides the potential for good memory performance (either by virtue of the item being different or by virtue of receiving extra processing). The appropriate retrieval cues help us solve a discrimination problem by providing us with the necessary information to choose from the responses available. Hunt and Smith (1996) applied the concept of distinctive processing – the processing of differences in the context of similarity – to the analysis of cue effects. In relational processing, participants have to note the similarities among the items which results in their organization into categories, but also increases the amount of feature overlap across the traces. According to Hunt and colleagues, if the primary benefit of relational processing is to restrict the target search set, then the primary benefit of item-based processing is to facilitate the discrimination of items within that set by reducing the amount of cue overload and the extent to which the cue predicts more than one targets (Nairne, 2006). Distinctiveness seems to be the result of encoding both similarities and differences among the discrete items. Processing item differences in a context of similarity is highly diagnostic of a particular item. Thus, the distinctive cue is thought to be reducing the target pool as it only shares certain features with a number of them (unlike the non-distinctive cue which brings to mind, more or less, all targets and the discrimination among them takes more time).

Based on the above, the distinctive conditions were considered to be more discriminative and were expected to improve memory performance. In Exp.4 (Chapter 3), the one-shared-distinctive condition yielded a faster target response than the one-shared-standard, but there was no such effect between the one-unique plus one-shared conditions. In Exp.5 (Chapter 3), no differences were found between the distinctive and non-distinctive conditions. An examination of the participants' gaze patterns in Exp.5 indicated that the preferential processing of the cues in the one-unique plus one-shared-standard condition was masking the distinctiveness effect (to be further elaborated in the next section). After, somewhat, controlling for cue processing in Exp.6 (Chapter 3), the one-shared-distinctive and the one-unique plus one-shared-distinctive conditions elicited faster responses than their respective standard conditions.

Returning to the cue processing issue, the drag-and-drop results showed that the diagnostic value of each cue determined whether it was selected first, second or last. The same selection pattern was found in two experiments in Chapter 3; the shared-distinctive cue was mostly selected first, while the standard shared cue was selected last. This preference towards the shared-distinctive and the unique cues was further confirmed by the eye-tracking results in Exp. 5 (Chapter 3). Another critical finding was the preferential processing of the cues observed in the one-unique plus one-shared-standard condition at test; participants made significantly more and longer fixations on the unique cue than on the shared-standard one. Interestingly, this was not found in the one-unique plus one-shared-distinctive condition; the amount and duration of fixations did not differ between the unique and the shared-distinctive cue. It appears that the shared-distinctive cue attracted as much processing as the unique cue.

In summary, results supported our hypothesis that participants actively process the cues based on their discriminative value and that they develop encoding strategies that serve the same purpose. In general, the discrimination power a cue holds could be manifested in different ways (e.g. meaningfulness or formal similarity), but it appears that processing is systematically biased towards more discriminative features in the environment. Participants favour the more diagnostic cues in the time of learning, as well as in the time of retrieval; they actively process the material allocating more time to the cues that hold more discriminative power (i.e. shared-distinctive, unique). In the studies reported here, it appears that the key determinant of cue processing, cue effectiveness and cue selection is discriminative value. In addition, the findings reported here clearly suggest that participants choose to encode / process cues in ways that modulate the discrimination problem posed to the memory system. Given the opportunity, participants selectively processed the relationships between shared / overloaded cues and targets in such a way as to transform nominal overloaded cues into functional cues that are more discriminative. Participants' effort to increase the shared cues' discriminative value can be seen as further indirect support for the memory-as-discrimination view which stresses the importance of the diagnostic power of the cues. This behaviour may be seen as effective and adaptive as it reduces the discrimination problem that several conditions pose; associating each shared cue preferentially to a given target in effect transformed a non-discriminative cue into a cue that supported the retrieval of a correct target. The downside is that, the same cue will be less effective (will elicit slower responses) in retrieving the alternative target. Also, by favouring processing of certain cues over others (e.g. the unique in the one-unique plus one-shared-standard condition), performance was enhanced compared to what it would have been if all the cues were processed evenly.

The implication of the above is that information processing outside the laboratory could, in many situations, be guided by the diagnostic value of the given stimuli. Let us consider one example: medical differential diagnosis. Various symptoms (consider them as the cues) are shared among several conditions (consider them as the targets), while others are unique. Our results from Chapter 2 suggest that as experience with the medical conditions and their symptoms develops, medical students and staff may inadvertently maximise the predictive power of some symptoms, reducing the relative amount of processing they devote to other less discriminative symptoms. If they behaved like the participants in the studies above, they might associate some of the shared symptoms mostly with a particular condition, while minimising its relationship to other alternatives. Could this lead to delay in considering some diagnoses? If the shared symptom is mostly considered a marker of illness X, then diagnosis of illness X will be faster. On the other hand, finding the same symptom clearly associated with illness Y might generate delay (or errors) in diagnosing Y. Conversely, Chapter 3 results also suggest that doctors may preferentially process the discriminative symptoms relative to the shared ones, a processing strategy that might support retrieval / the correct diagnosis.

There is substantial literature on learning and attention that relates to the ideas described here. It is neither feasible nor within the scope of this thesis to review it, however a brief mention will be made to stress the parallelism among the fields (learning, attention and memory). Kamin (1968) first reported the phenomenon of *blocking* in learning: in a situation where two cues, A and B, are presented along with an outcome, they both acquire moderate associative strength with it. Nonetheless, if the subject learned, in a previous session that cue A on its own predicts the outcome, cue B acquires a weak associative strength with the outcome when presented later on in combination with cue A. Prior learning with cue A *blocked* learning about B. The Rescorla-Wagner model (non attentional learning) states that in the AB+outcome trial (blocking trial) which followed the A+outcome trial, the outcome is not sufficiently processed because cue A already predicts it. This results in inadequate learning of the association between B and the outcome (Griffiths, & Mitchell, 2008). The Mackintosh model (1975) predicts the same result but due to attentional reasons. Mackintosh proposes that in the AB+outcome blocking trial, people do not attend cue B adequately because it is less predictive than cue A. Once participants learn which cues effectively predict the outcome, they increase attention to those cues and decrease attention to any other cues presented simultaneously. Like Mackintosh, Krusche (2001) proposed the EXIT model which suggests that attention is learned to be preferentially directed to the most predictive cue (e.g. A) when it part of a cue compound (e.g. AB trial). All these models describe situations similar to the ones presented in this thesis. However, these models are theories of learning, not memory, and therefore do not make any direct predictions about memory performance.

We also need to clarify that not all interference reduction is due to cue discrimination. The former could still occur no matter what shared cue-attributes are processed to generate distinctive codes. It is, also, accepted that the evidence provided so far may not be sufficient to clearly establish that participants use the discriminative cue-features to differentiate targets on a usual basis, or that the discriminative power controls cue processing most of the time. Regardless, it is argued that this thesis has provided enough evidence to allow this view to be considered and further tested.

4.3. Future research

The present thesis is a stepping stone in further investigation of the relationship between the discriminative value of cues, cue processing and cue effectiveness. More research is needed to establish whether the response strategy observed in Exp.1 and 2 (Chapter 2) can be generalised to other tasks/situations. Is this a strategy that people commonly adopt in the face of shared cues? If such a processing is indeed an everyday occurrence, this could mean that, the ‘contamination’ of results introduced by the response strategy could actually be the norm and could have numerous implications. It could well be that in everyday life information processing is guided by the information value of the stimuli and results to the strategic processing of the shared cues (associating them with just one target) in an effort to increase discrimination power.

Additionally, when moving into the future, the patterns of results from Chapters 2 and 3 should be considered together. Further research is needed if a model of the processes involved in the scenarios described here is to be developed. The simplified retrieval model that was used to illustrate the memory-as-discrimination view is not sufficient to account for our data for two reasons. First, the current formula - and many other models - is about predicting the probability something will be recalled (or not) rather than predicting the speed at which it will be recalled. This is a limitation of this thesis, as the main measure of performance was response time and further research using accuracy data is needed. Second, in this simplified instantiation, memory-as-discrimination assumes that a cue’s features are compared to the relevant targets within the retrieval set and that retrieval probability of a given cue-target pair is determined by the relative distinctiveness of their link. Each cue-target comparison is equally weighted in this process. Based on the current findings, one could say that, the strength with which a shared (overloaded) cue is processed with a given target attributes a certain “weight” to that cue, which subsequently modulates competition at retrieval. The repeated selection of a target when a shared cue is presented, as observed in Exp.1 and 2 (Chapter 1), can be seen as modifying the weight of that cue-target pair, relative to the other cue-target comparisons involving the said cue. As the number of times a target is chosen in response to a shared cue increases, the ‘weight’ of the shared cue-target comparison could be seen as increasing as well. In theory, response time in the one-unique plus one-shared condition should vary as a function of the shared cue’s weight; analyses of response times in Exp.1 and 2 suggest that the more ‘weight’ a cue acquired, the faster the response times it elicits will be. Additionally, our results (Exp.5, Chapter 3) clearly show that all shared cues are not treated the same and some attract more processing than others (i.e. shared-distinctive versus shared-standard). This may have resulted in the shared-distinctive cues acquiring more ‘weight’ relatively to the shared-standard cues. This preferential cue processing may be accentuated under time-pressure. Future research could factor in, if and how time constraints alter cue processing patterns and cue weights.

In principle, the results are in agreement with the memory-as-discrimination view - it is the discriminative value of each cue that matters. The memory-as-discrimination view could predict memory performance more accurately if a model was proposed that could account for response time effects, as well as for the strategic cue processing and their acquired “weight”. Further investigation of the circumstances that - and the extent to which - cue processing affects cue’s discriminability would be valuable in the refinement of such a model. 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.

4.4. Conclusion

The empirical work presented in Chapters 2 and 3 provided evidence in favour 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. The memory-as-discrimination view illustrates the retrieval processes more accurately; increasing encoding-retrieval match is not relevant to memory performance, while the main determinant of retrieval is the discrimination power of the cues. Discrimination power may be a consistent factor throughout the memory retrieval process (in the present thesis as well as in previous work e.g. Poirier et. al., 2011), but the amount of cue diagnosticity can also be manipulated by strategic cue processing. When the present thesis is considered, it allows for the identification of more specific interactions within the discrimination power effects. Features of the encoding environment are able to alter the amount of processing each cue receives altering the cue’s discrimination power. Subsequently, it is reasonable to predict that varying levels of discrimination power would result to varying retrieval performance. The question remains: Can memory-as-discrimination view make even more accurate predictions if it accounts for response time effects and the differential cue processing (‘weights’)?

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