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Memory as Discrimination:

A Challenge to the Encoding-Retrieval Match Principle

Marie Poirier[1]

City University London

James S. Nairne

Purdue University

Caroline Morin

Cranfield University

Friederike G.S. Zimmermann

Maastricht University

Kyriaki Koutmeridou & James Fowler

City University London

Abstract

Four experiments contrasted the predictions of a general encoding-retrieval match hypothesis with those of a view claiming that the distinctiveness of the cue-target relationship is the causal factor in retrieval. In Experiments 1, 2, and 4 participants learned the relationships between four targets and trios of cues; in Experiment 3 there were three targets, each associated with a pair of cues. A learning phase was followed by a cued-recognition task where the correct target had to be identified based on one or more of the cues. The main performance measurement was response time. Learning was designed to lead to high accuracy so effects could be attributed to retrieval efficiency rather than to variations in encoding. The nature of the cues and targets was varied across experiments. The critical factor was whether each cue was uniquely associated with the to-be-recalled target or not. All experiments orthogonally manipulated 1) how discriminative—or uniquely associated with a target—each cue was and 2) the degree of overlap between the cues present during learning and those present at retrieval. The novel finding reported here is that *increasing* the encoding retrieval match can *hinder* performance if the increase simultaneously reduces how specifically cues predict a target—that is, a cue's diagnostic value. Encoding-retrieval match was not the factor that determined the effectiveness of retrieval. Our findings suggest that increasing the encoding-retrieval match can lead to no change, an increase, or a decrease in retrieval performance.

Memory as Discrimination:
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One of the most fundamental questions that research on human cognition has to answer is how we remember – or retrieve information from memory. A better knowledge of this process will contribute to our understanding of normal memory functioning, of forgetting, and of the memory problems that accompany various illnesses and brain disorders. When considering memory from this perspective, we are referring to explicit and conscious attempts to retrieve events or information from our past —we are referring to recollection— or what is typically known as retrieval from explicit/episodic memory (Tulving, 2002).

One of the most widely held views in this field is that memory performance depends on the encoding-retrieval match—the extent to which encoded retrieval information overlaps with or matches the to-be-recalled representation (e.g. Eysenck and Keane, 2010). In this paper, we set out to test a controversial view that insists that the encoding-retrieval match, as it is habitually construed and portrayed, cannot predict retrieval efficiency. Below, we first briefly introduce and differentiate some of the major ideas in the field: encoding specificity, encoding-retrieval match, and cue overload. After concurring that the encoding-retrieval match view is very influential, we review a proposal that challenges the value of the encoding-retrieval match idea.

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Nairne's (2005) championed this view and clarified its implications; like Hunt (2003), he insisted that successful retrieval is not just about selecting the correct target; it is about rejecting the incorrect ones also. This perspective, hereafter identified as memory-as-discrimination, requires a more systematic consideration of the conjoint roles that encoding-retrieval match and cue overload play in memory retrieval. Adopting the perspective of memory-as-discrimination led us to the realisation that their mutual influence should be

Formatted: English (U.S.), Do not check spelling or grammar, Highlight studied together. More specifically, the suggestion is that without considering both encoding-retrieval match and cue overload ~~being~~ in concert, clear predictions relative to retrieval cannot be made. By considering both in a more formal way, memory-as-discrimination ascribes a role to each and insists that a) both play a role in *all* cases of memory retrieval and b) clear predictions about retrieval cannot be made without considering their simultaneous influence.

Importantly, adopting the memory-as-discrimination perspective led us to a counter-intuitive prediction—one that would not be derived from the more usual perspectives: under a number of circumstances *increasing* the encoding-retrieval match will *hinder* retrieval. We present four experiments that systematically tested this hypothesis in the context of a cued-recognition task where retrieval efficiency is measured through response time. Before describing these ideas more fully and formally, we first briefly revisit the main related concepts.

Encoding specificity

Although many equate encoding specificity and encoding-retrieval match, the concepts are not the same. When the encoding-specificity concept was first introduced, its predictions were contrasted with those of the generate-recognise models of the time (e.g. Bahrick, 1969; Anderson & Bower, 1972). These models suggested that any cue that was suitably related to a target could support and enhance retrieval—even if it was not encoded with the to-be-recalled event. Simply put, the logic was that such extra-event cues, because of their prior relationship with the targets, would increase the probability that the target would be generated and then recognised as a desired retrieval object. Through a series of studies—including, notably, those on the recognition failure of recallable words—Tulving and his collaborators refuted this idea and suggested in its stead the encoding-specificity hypothesis [see Tulving (1984) for a summary of this debate]. In this context, the essential meaning of encoding specificity was captured in the following (where TBR stands for to-be-retrieved): "The encoding specificity hypothesis, among other things, clearly implies that no cue, however strongly associated with the TBR item or otherwise related to it, can be effective unless the TBR item is specifically encoded with respect to that cue at the time of its storage." (Thomson & Tulving, 1970, p. 255).

In other words, the encoding-specificity hypothesis insists on the *necessary* relationship between the retrieval cue and what was processed at encoding; the idea is that unless the cue was part of the encoded information it cannot lead to successful retrieval. However—and importantly—encoding-specificity is often *considered* synonymous with the encoding-retrieval match idea; in other words, encoding-specificity is often misrepresented to imply that an increase in the encoding-retrieval match will lead to an increase in the probability of recall or recollection.

Encoding-retrieval match

There are currently many areas of research where the encoding-retrieval match idea is used to predict and interpret findings. In contemporary research, encoding-retrieval match has underpinned work examining context-dependent, mood-dependent, and state-dependent memory (Roediger & Guynn, 1996; Smith & Vela, 2001). This is because it is often suggested that when attempting to recall a given episode, the re-instatement of the environmental context, or of the mood or state that accompanied the original encoding, can support retrieval by increasing the match between the current cueing information and the to-be-retrieved event. There are numerous other recent examples of research calling upon this hypothesis. A sample includes: work examining the role of colour in memory for natural scenes (Spence, Wong, Rusan, & Rastegar, 2006), experiments exploring the influence of encoding-retrieval match on prospective memory performance (Hannon & Daneman, 2007), and studies investigating the misinformation effect (Campbell, Edwards, Horswill, & Helman, 2007).

Moreover, a related concept is proving influential in cognitive neuroscience namely, the reinstatement hypothesis. This hypothesis stipulates that the recollection of a recent episode is possible when a pattern of cortical activity corresponding to the episode is reinstated in the brain via processing of the retrieval information. The hypothesis has been the focus of several studies using techniques such as functional magnetic resonance imaging and its discussion typically refers back to the encoding-retrieval match idea [see for example Johnson & Rugg (2007) and Polyn, Natu, Cohen & Norman (2005)].

In effect, a perusal of current literature makes it fairly straightforward to conclude that with a few exceptions, the encoding-retrieval match hypothesis is as uncontroversial as they come in cognitive psychology and cognitive neuroscience.

Cue Overload

Importantly however, many memory researchers would qualify the encoding-retrieval match hypothesis by introducing the concept of cue-overload (Capaldi & Neath, 1995; Craik & Jacoby, 1979; Earhard, 1967; Eysenck, 1979; Hunt & Smith, 1996; Roediger & Guynn, 1996; Watkins & Watkins, 1975; Watkins 1979). The cue overload hypothesis states that as the number of items in memory associated with a cue increases the effectiveness of the cue declines. For example, Craik and Jacoby offered the following: “We postulate that retrieval will be successful to the extent that retrieval processing matches encoding processing. 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.” (Craik & Jacoby, 1979, p. 158). According to this proposal then, both encoding-retrieval match and cue overload play a role in determining the probability of successful recall. In the Craik and Jacoby paper, an experiment by Craik and Tulving is reported where cue-overload is manipulated. This is done by using a given cue for either, one, four, or eight targets. The results provide a clear example of cue overload in operation as retrieval success was inversely proportional to the number of targets associated with a given cue.

The cue-overload effect is a well documented and reliable finding but as in the statement by Craik and Jacoby (1979) it is often considered as a less potent and optional source of interference with the dominant causal influence on performance being the encoding-retrieval match. Recently, Nairne (2001, 2002) challenged the idea that the encoding-retrieval match played a veritable causal role in performance and insisted on a view where retrieval is conceived of as a discrimination problem.

Memory-as-Discrimination

Nairne (2001, 2002) suggested that increasing the encoding-retrieval match tends to have a positive effect on performance because it is usually correlated with an increase in the cue’s power to discriminate between the target item and any competitors in the retrieval set. According to this view, what matters is the diagnostic value of the cue: although some relationship between the cue and target is necessary—in agreement with the encoding-specificity principle—what really determines the probability of recall is the degree to which a cue is uniquely associated with a given target, *to the exclusion* of other potential retrieval candidates. In effect, this proposal suggests that both encoding-retrieval match and cue overload *must* be considered in every retrieval event. Moreover, it insists that causation cannot be attributed to either of these effects alone. Together, they determine a cue’s discrimination power and it is this discrimination capacity that causes retrieval success or failure.

As Nairne (2006) pointed out, the idea that memory depends on the relative distinctiveness of the cue-target relationship is not new in the memory literature (e.g. Craik & Jacoby, 1979; Hunt, 2003). However, as we alluded to earlier, the implications of this view have generally been overlooked. More specifically, the memory-as-discrimination view predicts that increasing the encoding-retrieval match can lead to an increase, no change, or a decrease in memory performance.

In order to make this clearer, consider a situation where an increase in the match between a cue and a target is accompanied by a corresponding increase in the match between the cue and other potential events or retrieval candidates – the outcome of this process would not necessarily be better performance. The outcome crucially depends on the relationship between a) the cue-target match *and* b) the cue-competitor match (or cue overload). The implication is that less could be more when it comes to the information available at retrieval. In other words, having very little encoding-retrieval overlap could be better than having considerable overlap if the small overlap involves a cue that is uniquely associated with the target while the larger cue constellation includes information shared with multiple competitors.

One way in which this analysis can be made explicit is by considering a simple choice rule, as often incorporated in memory and categorisation models (Nairne, 2001, 2002; Nosofsky, 1986). This choice rule states that the probability that a particular event, E_1, will be retrieved from memory depends on how well a cue, X_1, matches (*s* for similarity) the target E_1 to the exclusion of other retrieval candidates (E_2 , E_3, …E_n), as follows:

$$P_r(E_1 \mid X_1) = \frac{s(E_1, X_1)}{\sum s(E_1, E_n)} \quad (1)$$

As can be deduced from the above, any estimation of P_r depends on the encoding-retrieval match –expressed in the numerator as the similarity (s) between the cue X_1 and that target E_1—and also on cue overload – here represented by the summed similarity between the cue and all the items in the retrieval set. In a nutshell, the proposition clearly suggests that our theories, models, and proposals need to steer clear from the encoding-retrieval match idea in its usual or accepted form. Increasing the encoding-retrieval match will only be beneficial if it means that the target can more easily be discriminated from competing retrieval candidates, i.e. if the numerator is increased proportionally more than the denominator.

From the above we can see that the memory-as-discrimination view suggests we *always* and systematically consider encoding retrieval match and cue overload. Importantly, cue overload is not considered as a secondary, optional influence on performance. The discrimination view insists that the power of a cue can only be determined by considering how well the retrieval information allows one to select amongst competing candidates.

This view directly leads to a counter-intuitive prediction: under the right circumstances, increasing the encoding retrieval match should lead to a decrease in performance. Importantly, although cue overload effects have been demonstrated often, there has never, to our knowledge, been a systematic examination of this more stringent test of the discrimination idea. Cue overload studies hold encoding-retrieval match constant and only manipulate the number of candidates associated with a given cue. Here, we set out to test the prediction that *increasing* the encoding retrieval match can lead to a *reduction* in the efficiency of retrieval (as indexed by response time – more about this below). More generally, we set out to examine the following idea: improving the encoding-retrieval match can lead to an increase, a decrease or no change in performance; it all depends on how the discrimination problem is affected by the increase in overlap between encoding and retrieval.

The cued-recognition task

The experiments reported herein relied on a cued-recognition task that allowed us to contrast the predictions derived from a general encoding-retrieval match view and the memory-as-discrimination proposal. The experimental task made it possible to manipulate both encoding-retrieval match and cue overload orthogonally. This task was called upon in all the experiments reported here; accuracy of performance is considered but the main performance measure is response time.

We chose response time for straightforward reasons. 1) We wanted to be confident that any effects were attributable to retrieval operations rather than variations in the encoding of cue-target relationships; so, in the cued-recognition task, a learning phase ensures the relationships between cues and targets are well established. 2) Based on previous findings in related fields, it seemed reasonable to assume that identifying a correct retrieval candidate from among a varying number of competitors doesn’t necessarily affect accuracy but should affect retrieval time. The memory as discrimination proposal is about selecting a retrieval target from among competitors – it is a fairly straightforward affair to suggest that an increase in the difficulty of the discrimination problem will lead to an increase in retrieval time (MacLeod & Nelson, 1984). A related idea has been clearly and elegantly demonstrated, for example, in the work on the fan effect showing that when more facts are known about a concept, the time to retrieve any specific fact about the concept increases (Anderson, 1974; Anderson & Reder, 1999). A few examples can serve to clarify these points. Consider a situation where target 1 is associated with cues X and Y. If recall accuracy is better with cue X than with cue Y, it can be because retrieval is easier with cue X relative to Y (if Y is overloaded for example) or it can be because Y was not as well encoded to begin with. With accuracy as the main measure of performance, it is not possible to disentangle these two possibilities. Furthermore, comparable accuracy levels can easily mask significant slowing attributable to more difficult discrimination between retrieval candidates. In such a situation cues X and Y would generate comparable accuracy, but because Y is associated with a greater number of retrieval candidates, the generation of a correct candidate would take considerably longer. Let us consider a last example, one that is closer to the conditions studied here; consider a situation where cue X is uniquely associated with the target, while

Formatted: English (U.S.), Do not check spelling or grammar, Highlight cue Y is associated with the same target and other retrieval candidates. Providing cue X alone or both cues X and Y could easily lead do comparable levels of accuracy, as cue X uniquely identifies the target. However, providing both cue X and Y could lead to significantly slower retrieval because of the more difficult discrimination problem created by the competing retrieval candidates. This way of thinking led us to favour response time over accuracy as the measure of choice for this first systematic test of the more counterintuitive predictions of the memory-as-discrimination view. We reasoned that with a task where accuracy is very high and differences are related to the efficiency or speed of retrieval, findings were more likely to be unambiguous and conclusions more readily drawn. We return to these issues in the discussion.

The task we used comprised a learning phase and a test phase. In the learning phase, participants had to learn which cues were linked to which targets. They knew 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. In all the experiments except one, there were four targets and four sets of cues, each cue set containing three items. In Experiment 3 there were three targets each associated with two cues. The targets varied in nature across experiments; they could be words, consonant-vowel-consonant non-words or CVCs (see Figure 1), or drawings of animals. The cues also varied; depending on the experiment they were geometric shapes, words, drawings of fruit, or drawings of objects. 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 1 provides an example of a cue-target set. In Experiment 1, we chose to use these relatively unfamiliar cues and targets to control for prior experience with the stimuli; this precluded prior learning from significantly influencing performance and reduced the chances that unitization of the cue trios would be an issue.

Insert Figure 1 about here

Perusal of the Figure 1 shows that some of the cues were shared between two targets whereas the others were uniquely associated to a single target. Given these shapes are called upon 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.

During the learning phase, participants were presented with the trio of cues, accompanied by the correct retrieval target – as illustrated in Figure 2. More details will be provided in the method section – here let us simply say that presentation involved a random selection without replacement of one of the target-cue sets, until all four had been presented and that this presentation was repeated a number of times. The position of the cues on the screen was randomly determined on each trial. The important point is that encoding of cues and target involved all three cues being presented, along with the to-be-retrieved target.

Insert Figure 2 here

The testing conditions were defined by the number and type of cues presented. There were four testing conditions. Participants were presented with either: one unique cue, two unique cues, one unique plus one shared cue, or one shared cue. Examples of these cue combinations are provided in Figure 3. The figure shows buttons below the presented cues, each identifying one of the retrieval targets. In Experiment 1, participants were asked to type their answer whereas in the subsequent experiments they were asked to click on the correct button / retrieval target. In all cases, they were asked to respond as quickly as they could, without introducing mistakes due to haste. The cues that were not presented were replaced by a small filled square, as illustrated. When a shared cue is presented on its own, two correct answers are possible. Participants were forewarned of this and told to only provide one of the correct answers on any given trial. As there are two possible answers in response to this cueing condition it is difficult to compare performance in this case to that found in the other cueing-conditions. We nevertheless included a one-shared condition in the testing to ensure that participants did not adopt a strategy where they ignored the shared cue.

Insert Figure 3 here

Given this task structure, what are the predictions of the encoding-retrieval match and memory-as-discrimination views? First consider the comparison between the one-unique and the one-unique-plus-one-shared conditions. Adding the shared cue to the unique cue increases the similarity between the retrieval conditions and the conditions provided at encoding; in other words, the encoding-retrieval match is increased. Hence, from an encoding-retrieval match perspective, we would expect more efficient retrieval and faster response times. However, the shared cue also reduces discriminability. The unique cue on its own specifies a single retrieval target; when the shared cue is added to it, the cue constellation now shares features with two retrieval candidates. It follows that according to the memory-as-discrimination view, the one-unique-plus-one-shared condition should lead to more retrieval interference and less efficient retrieval compared to the one-unique condition. Hence, the prediction from this point of view is that the one-unique-plus-one-shared condition will lead to slower retrieval relative to the one-unique condition. So, regarding the comparison between the one-unique condition and the one-unique-plus-one-shared condition, the predictions of the memory-as-discrimination and encoding-retrieval match views oppose each other.

What about the two-unique cueing condition? Relative to the one-unique condition, the two-unique cue condition again represents an increase in the encoding-retrieval match, as two of the three cues repeatedly presented during learning are provided at retrieval. The encoding retrieval match perspective would hence predict an improvement in performance. With respect to the memory-as-discrimination view, the prediction is similar but qualified. With respect to accuracy, Equation (1) above predicts an improvement in performance as the numerator would be increased but not the denominator. Also, if one assumes that the relationship between each unique cue and the target is somewhat uneven, it means that presenting a single unique cue would be slightly less efficient 50% of the time. However, when two unique cues are presented the better learned cue would on average improve retrieval efficiency. Hence, depending on how well each unique cue predicts a target, the memory-as-discrimination hypothesis predicts an improvement when going from one-unique to two-unique cues. With respect to response time, when one-unique cue is presented, the target is specified; the same is true when two-unique cues are presented. One would expect that if two cues resonate with the same target, without any increase in the number or strength of competitors, some improvement in response time should be seen.

To summarise, 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, provided the cue constellation uniquely identifies one of the targets. 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 improve slightly when two-unique cues are presented. Experiment 1 examined which one of these sets of predictions was supported.

EXPERIMENT 1

Participants

Twenty-seven psychology undergraduate students from City University London participated in the experiment. They received course credits for their participation.

Materials & Design

The task involved learning to associate non-words (consonant-vowel-consonant or CVC trigrams) with simple geometrical shapes; the latter served as cues in the memory test. A total of eight CVCs were used, separated into two sets of four. The CVCs were equated in terms of neighbourhood size and frequency of neighbours. Moreover, as will be explained below, each CVC served as its own control. The geometrical shapes were created with the standard Microsoft drawing tool. Each shape was centred within a white rectangle of fixed size (170 x 140 pixels). The shapes themselves varied in length, width and colour but were all of similar sizes (see Figure 1). As Figure 1 shows, cues could either be uniquely associated with a given CVC target or be associated with two of the targets. Four cueing combinations were called upon in the memory test, defined by the nature and number of cues presented; these were: one-unique, two-unique, one-unique plus one-shared, and one shared. The latter was included so we could establish that participants learned the shared cues. Presentation of these stimuli, timing, and response recording were all done with the help of a personal computer, controlled through a Macromedia Authorware program. Response time was recorded with millisecond precision (McGraw, Tew, & Williams, 2000).

Procedure

Participants were individually tested within one session lasting approximately 20 minutes. All stimuli were presented within a white task window (800 x 600 pixels), centred in the middle of the computer screen. The session comprised two consecutive learning-test cycles. Each cycle involved four different non-words and 10 separate shapes (as in Figure 1). None of the shapes or non-words was repeated from one cycle to the next. The first cycle was considered as familiarisation with the task and task requirements; pilot testing indicated that participants typically reached the set performance criterion (minimum 60% correct in each testing condition) in the second learning and test cycle [pilot testing indicated that many participants at first believed the task to be somewhat easier than it actually was – the first block of test trials allowed most to adjust their estimates of task difficulty and, if necessary, to put more effort into encoding cue-target relationships]. Hence, although participants were not informed of this, the first cycle of learning and test was not analysed; only the results of the second cycle were considered.

For each learning-test cycle, the associations between to-be-recalled non-words and the shape-cues first had to be learned; this was done by presenting each CVC and associated shape-cues a total of 12 times (details below). Which set of CVCs was associated with a given set of cues was counterbalanced across participants, as was the order in which each set of target CVCs was encountered. Once a learning session was completed, it was followed by a testing phase where memory for each non-word within the set was tested with varying subsets of cues. The sequence of events was as follows.

Training phase. In the first half of each training phase, one of the four non-words was randomly selected and presented, in 36-point font, in the centre of the task window. All three cues were simultaneously presented with the target. They appeared 1 cm above the target, in a row, centred relative to the task window. The target and cues remained on the screen for 3 seconds and the order of the cues on the screen was randomly determined on each trial. After a 1 sec pause, a new non-word was randomly selected and the process was repeated until all four sets of CVCs and cues had been presented. This cycle was repeated until each CVC-cue set appeared twelve times.

Test phase. Each learning phase was followed by a test phase involving 32 trials, eight for each CVC target. In effect, each target was tested with the following combinations of cues: 1) two trials with one unique cue where each of the unique cues associated with each target was used in turn; 2) two trials with one unique and one shared cue – the shared cue was used once with each of the possible unique cues; 3) two trials where both the unique cues were presented and finally 4) two trials where only the shared cue was presented (there were 2 correct answers in this case and participants were forewarned of this in the instructions). The order in which these trials were administered was randomly determined for each participant, within each test bloc. The sequence of events for each test trial was as follows.

The participant initiated the first trial by pressing the enter key. One second after this, one of the combinations of cues described above appeared. Cues were presented simultaneously, in a row, adjacent to each other, at the same height where they appeared during learning. As all three cues were never presented, the missing item(s) were replaced by a small filled black square (15 x 15 pixels); which of the three possible positions this black square appeared in was randomly determined. Which one of the three possible positions on the screen a given cue occupied was determined randomly for each trial.

Participants answered by clicking on one of four buttons. They were asked to click on one of four rectangular white buttons which each contained the name of one of the targets (Arial 14 point font; see Figure 3). The response buttons were arranged in a semi circle below the row of cues (see Figure 3). For each trial, the position of the cursor was reset, immediately after cue presentation, in such a way that the cursor appeared below the buttons and was equidistant from the centre of each button. Reaction time was measured from the appearance of the cues until the participant clicked on one of the response buttons. Once the first 32 trials had been presented the second training session began with a new set of four CVCs as well as a new cue set.

Results and Discussion

Performance was scored for accuracy and median RT for correct trials was obtained for each participant and condition. To be included, participants had to achieve at least 60% performance in each tested condition. This was to ensure that instructions were being followed, that cue-target associations were well learned and that there were a reasonable number of trials to estimate mean RT from for each participant in each condition. The first bloc of test trials (Cycle I) was not included in the main analyses. Perusal of participants' performance revealed that only six of the 27 participants reached the set criterion in Cycle I. In Cycle II, only three out of 27 participants did not meet the set criterion.

The first column of Table 1 presents the accuracy data for the second cycle of test trials averaged across the 24 participants that met the performance criterion. The first column of Table 2 presents the equivalent RT data. As can be seen, accuracy is uniformly high across conditions with the two-unique condition showing a slightly elevated accuracy relative to the other conditions. With respect to RT, performance in the one-unique-plus-one-shared condition is clearly slower than the response times in the one-unique and the two-unique conditions.

The results were submitted to two separate repeated measures analyses of variance (ANOVA), one for accuracy and one for RT results. Each ANOVA had one three-level within-subjects factor (cueing conditions: one-unique, one-unique plus one-shared, and two-unique). The inferential analyses did not include the one-shared condition because it yielded two possible correct responses. Again, this condition was tested simply to ensure that participants did not adopt a strategy of ignoring the shared cues. We have included the average results for the one-shared condition in Table 1 and 2 for the sake of completeness and to show that participants were processing these cues adequately (none of the patterns of results change if the one-shared condition is included in the analyses).

The overall accuracy analysis showed no reliable effect of cueing conditions. With respect to response times, there was a significant effect of cue type [$F_{(2,46)}$ = 5.53, MSE = 0.14, $p < 0.01$]. Planned comparisons revealed a significant increase in response time for the one-unique plus one-shared condition compared to the one-unique ($t\ (24)$= 2.77, $p < 0.02$, [one-tailed]) and to the two-unique conditions ($t(24)$= 2.46, $p < 0.03$, [one-tailed]). There was no reliable difference between the one-unique and two-unique cueing conditions.

The results of Experiment 1 can be summarised as follows. Accuracy was high in all conditions, with average performance superior to 90% in all cases. With respect to response times, the findings show that responses in the one-unique plus one-shared condition were slower than in the two other conditions.

However, one alternative interpretation of this pattern of results takes into account the fact that cues are arranged horizontally in a row, above the response buttons. Perhaps participants are processing the cues from left to right, serially. In that case, encountering the shared cue first could slow participants down, whereas encountering the unique cue first would allow them to ignore the shared cue. In order to examine this possibility, we compared the response times obtained on trials when the shared cue was presented first relative to the trials where it was presented second in the one-unique-plus-one-shared condition; the results of this comparison can be found in the first row of Table 3. As can be seen, when the unique cue was presented in the left position, response times were nominally slower; however, this difference did not approach significance. Based on these results, we feel reasonably confident that the serial processing interpretation described above cannot account for the results obtained in this experiment.

Overall, increasing the encoding-retrieval match by going from one-unique cue to two cues leads to either no change in RT—in the case of two-unique cues—or to reduced performance—in the case of one-unique-plus-one-shared-cue. When we consider the contrast between one-unique cue 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 among the candidates in the retrieval set. Increasing the match by adding a cue that was shared amongst two targets was enough to significantly slow performance relative to a situation where a unique cue was presented on its own. Moreover, there was no reliable difference between the one-unique and the two-unique cueing conditions. Although some advantage was expected for the two-unique condition, this finding nevertheless shows that the critical difference in RT found between one-unique plus one-shared on the one hand and one-unique on the other cannot be solely attributed to the requirement to process two cues. Both the one-unique-plus-one-shared condition and the two-unique cue condition required the participant to process two cues, and were equated in terms of the encoding-retrieval match, but response times were significantly slower in the one-unique-one-shared condition. Although the requirement to process two cues may have slowed responding relative to the one-unique-cue condition, the diagnostic value of the two cues clearly played a role in the speed of overall responding.

EXPERIMENT 2

One general concern relating to the first experiment could be that they involved non-words and relatively abstract geometrical shapes. We chose to do this so that the prior experience with the stimuli could be well controlled. However, one can ask whether the results obtained would hold if different, more familiar, stimuli were called upon. This issue was examined in Experiment 2 which used words; compared to Experiments 1, the items called upon were more meaningful, concrete and familiar. More specifically, verbal stimuli were used for both targets and cues. Moreover, the nature of the task was made less arbitrary by the choice of stimuli – the targets were first names while the cues were trios of adjectives chosen to represent personal characteristics. Participants were asked to learn what qualities each person (name) exhibited. They were told that after the learning phase, they would be presented with one or two of the adjectives and that they would have to remember which person showed these characteristics.

Table 4 provides an example of the type of stimuli called upon in Experiment 2. As a perusal of the table shows, for each first name there were two unique and one shared descriptors. As in the first experiment, there were two cycles of learning and testing. As before, the first learning and testing cycle was considered as task familiarisation and only the data from the second cycle was submitted to analysis.

Insert Table 4 here

Method

Participants

Twenty-four undergraduate students from City University London participated in the experiment. They received £5 for their participation.

Materials & Design

The to-be-recalled targets in this experiment were sets of four first names; half of them were male and half of them female. The cues comprised 20 descriptive adjectives, organised in two sets of 10 (one per learning and test cycle), which were equated in terms of frequency, familiarity, concreteness and imageability. Each target stimulus (name) was associated with three cues; one of these cues was shared with another of the names while the two others were unique. As in the previous experiment, there were two cycles of learning and test, each involving four target names and 10 adjective-cues; none of the names or adjectives was repeated from one cycle to the next. Half of the participants were first presented with one of the sets and proceeded to the experimental block where the second set would be used. For the other half of the participants, the reverse order of sets was used. As in the previous experiment, testing involved the following cueing conditions: one-shared, one-unique, one-unique plus one-shared, and two-unique. The presentation of the stimuli and collection of responses was controlled by a program developed with Macromedia Authorware 7; as before, participants responded by clicking on the appropriate button (details below).

Procedure

The procedure in this experiment was identical to the previous one with a few small changes. Rather than being printed within the response buttons, the target names were displayed 5 pixels above the buttons, in 24 point Arial font. The clickable buttons were again arranged in a semi-circle but set slightly further apart so the names could be adequately displayed. As before, the cursor position was reset for each trial and it appeared below the buttons, in a position that was equidistant from each of them. The instructions to participants were essentially the same as in Experiment 1, except for the few changes made to accommodate the new type of stimuli.

Results and Discussion

As before, performance was scored for accuracy and response times for correct trials were analysed. In order to prevent the influence of outliers on response time, the median response time per condition used as the measure of RT for each participant. The first block of test trials was not included in the main analyses. However, perusal of participants' performance for this bloc revealed that 8 of the 24 participants did not reach the criterion level of performance of 60% in each condition. In cycle II, all participants met the set criterion except one.

The second columns of Table 1 & 2 respectively present the average accuracy and response time data for the second cycle of test trials (N = 23). As in the previous experiment, accuracy is uniformly high across conditions with the two-unique condition again showing slightly superior accuracy. With respect to response time, performance in the one-unique plus one-shared condition was slower. The results were submitted to two separate within-subjects one-way ANOVAs, one for the accuracy data and one for the RT results.

The analysis for accuracy showed a significant effect for cue type ($F_{(2, 44)}$= 3.35, p < 0.05). Means comparisons showed that the only significant difference stemmed from the slightly better accuracy in the two-unique condition relative to the one-unique condition ($t(22)$= 2.85, p < 0.01, [one-tailed]).

The results for RT revealed a significant effect for cue type [$F_{(2, 44)}$= 5.18, p < 0.01]. Planned comparisons again confirmed that the one-unique plus one-shared cueing condition was slower than the one-unique cue condition ($t(22)$= -2.54, p < 0.02, [one-tailed]) and the two-unique cue condition ($t(22)$= 2.62, p < 0.02, [one-tailed]). There was no reliable difference between the one-unique and the two-unique conditions. As was the case in Experiment 1, we examined the one-unique-plus-one-shared condition in more detail by comparing the median RT obtained on the trials when the shared cue appeared on the left to the median RT for trials when the unique cue appeared on the left. This comparison was of particular interest here as the use of words as cues might encourage a left to right processing strategy. The relevant means and t-test results are presented in the second row of Table 3. As in the previous experiment, there was no reliable difference between the two types of trials.

This experiment examined performance on the cued recognition task used here with different stimuli to the ones called upon in Experiments 1; the stimuli called upon here were all verbal and familiar. Instead of abstract geometrical shapes, Experiment 2 used words that depicted personal characteristics. Also, instead of having non-words as targets, this experiment used familiar first names. Experiment 2 replicated the pattern of results of the previous studies and generalised it to meaningful verbal stimuli. In both experiments, the response time pattern of results obtained was in line with the memory-as-discrimination approach and is difficult to interpret from an encoding-retrieval match point of view.

EXPERIMENT 3

This experiment examined performance on the cued-recognition task using different stimuli from those employed in Experiment 1; the stimuli were changed so that each of the four targets was associated with one unique cue and *two shared cues*. This allowed us to test a counterintuitive prediction that can be derived from the memory-as-discrimination view: two shared cues which together uniquely specify a target should produce significantly worse performance than all the other cueing conditions, including: one-unique cue, one-unique plus one-shared, and one-unique plus two shared (a complete cue set). We return to this prediction after briefly describing the stimuli used here.

The stimuli called upon in Experiment 3 were once again meaningful and concrete. We used drawings of the furniture contained within hypothetical rooms, each room being identified with a name. There were four such rooms, each containing a bed, a bookcase and a sofa. The furniture elements were always in the same spatial arrangement, with the bed to the left of the rectangle defining the room, the bookcase in the centre and the sofa to the right. The furniture elements constituted the cues and the room names were the targets. The arrangement of target and cues is presented in Table 5.

Insert Table 5 about here

As can be seen from Table 5, together, the two shared cues accompanying a given target were associated with three of the four targets. However, the conjunction of the two shared cues uniquely specified one of the rooms. The complete set of conditions tested in Experiment 3 were: 1) one-unique cue, 2) one-shared (for the same reasons as in previous experiments) 3) one-unique plus one-shared, 4) two-shared, and 5) one-unique plus two-shared. It should be noted that the last condition involves a complete reinstatement of the cues presented at learning, in their original format and order. Based on the memory-as-discrimination view, if the conditions are ordered in terms of predicted performance, the best condition should be the one-unique condition. This is because the unique cue specifies the target and is not explicitly associated with any other targets. The second best performance should be associated with the one-unique plus one-shared condition, as the unique cue specifies the target but the shared cue introduces competition from another item in the retrieval set. This should be followed by the one-unique plus two-shared; here three of the four target should be brought to mind but the unique cue specifies the correct item. Finally, memory-as-discrimination predicts the worse condition should be the two-shared case as three of the four targets should be brought to mind with no disambiguating cue: it is the relationship between the two shared cues that specifies the target.

The prediction from an encoding retrieval match perspective would be that with the addition of each cue, as the match increases, performance should improve. However, this prediction is complicated by the fact that an increase in the match involves an increase in the number of cues to encode. Hence, in this case, the critical comparison will be between the one-unique plus one-shared condition and the two-shared case, as the number of cues is held constant and the straightforward prediction is equivalent performance.

A few changes were made in the general procedure of this experiment. Piloting showed that having each target specified by one unique and two shared cues made the task considerably more difficult, with up to half of the participants not reaching the 60% performance criterion. In light of this, we lowered the criterion slightly to a minimum of 50% in each condition. Also, there were two learning and test cycles here as before; however, in this experiment, both cycles were conducted with the same stimuli and the same target-cue pairings in order to increase performance for the analysed cycle.

Method

Participants

A total of 36 participants took part in the study; they were undergraduates at City University and received course credits for their participation.

Materials

The materials were four sets of digitized drawings, prepared for this experiment, representing rooms, each with associated with a name. Each room contained three items, which were the cues in this experiment: a bookshelf, a bed and a sofa. The three cues were then associated with a target, which was the room name. The four room names were matched on concreteness, familiarity, imageability, and number of letters. The specific arrangement of cues for each target is described in Table 5. Each picture was full screen on a 15” computer monitor. As before, the task was computer controlled through a specially developed Authorware 7 program.

Procedure

Participants were individually tested within one session lasting approximately 30 minutes.

Learning phase. The experiment consisted of two identical study-test cycles; as in the previous experiments, the first cycle was considered as part of the training. Each cycle took approximately 15 minutes to complete. The aim of the task was for the participants to learn to associate room names with the items in each room. After the instructions, six presentations of the four different rooms appeared in a random sequence. During each presentation, the room name became visible at the top middle portion of a blank white screen, for one second. Then the picture of the room appeared below it, for six seconds.

Testing phase. Immediately after the learning phase, the testing phase began. There were five cueing conditions (one-shared, one-unique, one-unique plus one-shared, two-shared, and one-unique plus two-shared). The five conditions were tested twice for each room creating a total of 40 trials, eight per condition. The order of testing trials was randomly determined for each participant. Each testing trial began with a blank screen (2 sec.) followed by the presentation of a room containing one, two or three cues, in their original position, as well as four response buttons. The buttons were identified with the room names and as before, the cursor appeared in a position that was equally distanced from all four buttons. The participants were required to click on the button of the room name which they believed corresponded to the presented items of furniture, as quickly as possible without haste introducing errors. The next trial began one sec. after the participant's response.

Once the first study-test cycle was completed, after a two-minute break, the second study-test cycle was started. The only difference between the first and second cycles was that for the second cycle, there were no detailed instructions provided as the participants were already familiar with the stimuli and task.

Results and Discussion

Accuracy and median RT data were collated (for correct trials) as in the previous experiments. Participants had to obtain 50% correct performance in each condition for their data to be included and only the second learning and test cycle was considered for analysis. Of the 36 participants, 12 failed this criterion in the first cycle while 32 reached it in the second cycle.

The third columns of Tables 1 and 2 present the mean accuracy data and the RT averages, respectively. An examination of these results suggests that the two-shared condition was less accurate and considerably slower than what is found for the other cue arrangements.

Two repeated measures one-way ANOVAs were carried out on the data, one for accuracy and one for response time. For accuracy, a significant effect of cueing condition was obtained $F\ (3, 93) = 19.64$, $p< 0.001$. Planned comparisons showed that the two-shared condition was less accurate than the other conditions ($t(31) >4$ and $p < 0.000$ for the three comparisons, i.e. two-shared vs. one-unique, two-shared vs. one-unique plus one-shared, two-shared vs one-unique plus two-shared); no other differences were significant. As for RT, a significant effect of cueing condition was also found, $F\ (3, 93) = 21.20$, $p < 0.001$. Planned comparisons showed that as expected, the two-shared condition was slower than all the others ($t(31) > 4$ and $p < 0.000$ for the three comparisons). The one-unique condition was associated with faster response times than one-unique plus one-shared ($t(31) = -2.06$, $p < 0.02$ [one-tailed]) and than one-unique plus two-shared ($t(31) = -3.26$, $p < 0.002$ [one-tailed]). The comparison between RT for the one-unique plus one-shared and the one-unique plus two-shared did not reach significance.

As before, we also examined the one-unique-plus-one-shared condition in more detail; the median RT obtained on the trials when the shared cue appeared on the left was compared to the median RT for trials when the unique cue appeared on the left. The relevant means and t-test results are presented in the third row of Table 3. As in the previous experiments, there was no reliable difference between the two types of trials.

The pattern of performance reported in this experiment is almost completely aligned with the predictions of the memory-as-discrimination view. The best performance and the fastest RTs were associated with the one-unique condition, followed by the one-unique plus one-shared and the one-unique and two-shared conditions. The worse cueing combination, as expected, was the two shared condition, even though this combination of cues together uniquely identified the target. The only discrepancy between the detailed predictions made at the outset and the pattern of results was that the one-unique plus two-shared condition was not significantly different to the one-unique plus one-shared, although the means were ordered in the predicted direction.

EXPERIMENT 4

In the preceding experiments, learning the cue-target combinations appeared to be relatively difficult for a number of participants. This was especially true in the previous experiment. Therefore, we wanted to be confident that the patterns of results obtained would also be reproduced in a situation where the task was clearly easier. In order to achieve this aim, a number of changes were introduced in Experiment 4, as follows: 1) the learning phase was modified in such a way that participants' performance had to meet criterion *before* they went on to the testing phase proper; they did not go on to the testing phase without reaching a criterion level of performance that was set at 75% correct in each condition; 2) as in the last two studies the stimuli called upon in Experiment 4 were concrete and meaningful; 3) the number of targets was reduced from four to three and 4) the number of cues associated with each target was reduced from three to two with the latter comprising either two unique or one unique and one shared cue (see Table 6).

This means that when we tested the one-unique-plus-one-shared condition, we were actually providing a complete cue set—that is, a stimulus complex that matched what the participants saw at encoding. This was also the case in the two-unique condition.

Nevertheless, the main prediction of the memory-as-discrimination viewpoint is that a complete cue including one-unique plus one-shared will make retrieval more difficult than either the two-unique or the one-unique cue conditions, which are more diagnostic with respect to the correct target.

In Experiment 4 the items used as to-be-retrieved targets were drawings of farm animals (see Table 6). The participants were told that their task was to learn each animal's favourite foods. These were represented by drawings of fruit.

Insert Table 6 about here

Method

Participants

Twenty-four psychology undergraduate students from City University London participated in the experiment in exchange for course credits.

Materials & Design

The to-be-recalled targets in this experiment included a set of three drawings of farm animals, while the cues were drawings of fruit. Each animal drawing was approximately the same size and presented within a rectangle of 245 by 165 pixels. As for the drawings of fruit, they were presented within a 145 pixel square box. There were two cues for each of the targets. One of the targets was associated with two unique cues while the other two were associated with one unique and one shared cue. Which pieces of fruit were associated with each animal and which was shared or unique was counterbalanced across participants. All the possible cue combinations were included in the test phase of this experiment, namely: one-unique, one-shared, one-unique-plus-one-shared, and two-unique. As before, the presentation of the stimuli and collection of responses was controlled by a program developed with Authorware 7. Participants responded by clicking on the image of one of the targets (details below).

Procedure

Each participant was tested individually in a session lasting approximately 15 minutes. As in the previous experiments, the procedure in this study involved a learning phase and a test phase. The learning phase in this experiment involved a somewhat different procedure, however, as participants had to reach 75% correct in each condition before proceeding to the testing phase proper.

After the instructions, each pair of cues and the associated target animal were presented twice, each time for 2.5 seconds, in a randomly determined order. The cues were displayed in the middle of the upper half of the screen and the target animal drawing appeared just below in a central position. Which cue appeared left or right was randomly determined on a trial-by-trial basis. The presentation of each trio was followed by a half-second blank screen and the following set of cues and target appeared. Once all three targets and cue sets had been presented twice, a series of learning phase test-trials began.

A ready prompt was displayed and the participant had to click on a button for a learning-phase trial to start. This involved 16 trials, in random order, four for each cueing condition (one-unique, one-shared, one-unique plus one-shared, and two-unique). In a test trial, the cues appeared in the same areas on the screen as used in the presentation described above; their left-right position was determined randomly on a trial-by-trial basis. When only one cue was presented, the absent cue was replaced by three asterisks in Arial 48 point font. Half a second after the cues were presented the three target animal pictures appeared in a semi-circle below the cues. The cursor appeared at the same time as the targets, in a position that was equidistant from all three targets. Participants then had to click on the appropriate target given the cues presented.

This procedure, involving a presentation of the cue-target pairings followed by a series of 16 tests was continued until one of two things happened: 1) participants reached the 75% criterion performance in each condition for two consecutive training-test blocks or 2) they completed 6 training cycles. If they did not reach criterion within 6 training-phase cycles, the experiment was terminated.

If the criterion was reached, they proceeded to the testing session proper where the test trials were identical to the ones described above – but there were no more reminders of the cue-target pairings. In the testing phase, there were three series of 16 trials, separated by short pauses for a total of 48 trials. Each series of 16 trials was structured such that there were four trials in each of the cueing conditions, the presentation order of which was randomly determined within each block of 16 trials. Hence, the completed testing session involved 12 trials in each condition. Response time was measured to the nearest msec. from the appearance of the targets to the click by the participant. Any participant that did not maintain the 75% criterion performance during the testing session was not included in the analysed sample.

Results and Discussion

As before, performance was scored for accuracy and response times for correct trials were analysed. Of the 24 participants that took part in the experiment, all initially met the performance criterion except one. However, two other participants failed to maintain the required level of performance throughout the test and were eliminated from the analyses (final N = 21).

As in the previous experiments, in order to prevent the influence of outliers on response time, the median response time per condition was used as the measure of RT for each condition and participant. The last column of Tables 1 and 2 present the mean accuracy and RT data for each condition, averaged across participants. As can be seen from Table 1, in all conditions, performance was at ceiling. As for RTs, Table 2 shows that, as predicted on the basis of the previous experiments and the memory-as-discrimination view, the one-unique-plus-one-shared condition is slower than both the one-unique and the two-unique conditions. The fastest response times were obtained with the two-unique cue condition.

The accuracy and RT results were submitted to two separate repeated-measures ANOVAs. As before, these analyses were run on all conditions except the one-shared condition. As would be expected from the data in Table 1 there were no reliable differences between the mean accuracy scores for each condition. The analysis of the RT data showed a reliable effect of cueing condition ($F(2,40) = 10.58$, MSE = 0.05, $p < 0.001$). Planned comparisons indicated that the one-unique plus one-shared condition was reliably slower than the one-unique condition ($t(20) = -2.89$, $p = 0.005$, [one-tailed]) and the two-unique condition ($t(20) = 4.73$, $p < 0.001$, [one-tailed]). The difference between the one-unique and two-unique was not statistically reliable.

Finally, as in previous experiments, for the one-unique-plus-one-shared condition, we explored the effect of the shared cues position. The median RT obtained on the trials when the shared cue appeared on the left was compared to the median RT for trials when the unique cue appeared on the left. The relevant means and t-test results are presented in the fourth and final row of Table 3. As in the previous experiments, there was no reliable difference between the two types of trials.

The pattern of results reported in the previous experiments was reproduced here with an easier version of the task and a more stringent performance criterion. What is novel about the findings of Experiment 4 is the fact that in this experiment the one-unique plus one-shared cue was a complete cue and its effectiveness had been ensured by a training period that brought proportion correct to a level above 98%. Nevertheless, response time in the one-unique plus one-shared condition was slower than in the one-unique condition. As before, this is difficult to attribute to having two cues to encode as the level of performance observed in the two-unique condition is numerically lower than in the one-unique condition, although this difference didn’t quite reach significance.

General Discussion

In the four experiments presented here, the efficiency or speed with which various combinations of cues could lead to the retrieval of a given target was explored. Our objective was to contrast two sets of predictions, one derived from the encoding-retrieval match principle and one from a memory-as-discrimination viewpoint. In these experiments each to-be-remembered target was associated with multiple cues and the relationship that the cues had with the targets could be of two types. Cues could be uniquely associated to a given target or they could be shared cues, i.e. they were associated with two targets. Shared cues could be of use in retrieving one of the to-be-remembered items as they were associated with a subset of the experimental targets, but unlike unique cues, they could not completely specify a target response on their own.

In these experiments, the critical comparisons involved performance when one unique cue was provided relative to when two cues were provided. Compared to providing a unique cue, presenting both a unique and a shared cue meant there was an increase in the encoding retrieval match; this is because two of the cues present at learning were available to support retrieval. Nevertheless, in all experiments the one-unique-plus-one-shared cue led to slower responding. Conversely, when the two-cue condition involved two unique cues, there was no change in performance relative to the one-unique cue condition. What is more, in Experiment 4, presenting two cues meant that all the cues presented during learning were provided at test. Nevertheless, in this experiment also, an increase in encoding-retrieval match lead to either a decrease in performance or no change. 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.

According to an encoding retrieval match view, performance should be enhanced as the overlap between the cues processed at encoding and those processed at retrieval is increased. It is easy to envisage a retrieval process in which this would be the case: Activation of the encoded target simply increases as a function of its overlap with the presented cues. However, the predictions of the memory-as-discrimination viewpoint are different. It proposes that increasing the encoding-retrieval match will only benefit performance if this increase in the match contributes to enhancing the cue’s capacity to discriminate among relevant targets in the set of possible target items.

It follows that the predictions of the encoding-retrieval match and that of memory-as-discrimination were at odds when the contrast between the one-unique cue and the one-unique plus one-shared cue conditions were considered. The results of all four experiments concur in supporting a somewhat counterintuitive prediction: increasing the encoding-retrieval match can lead to a decrease in performance if the increased match contributes to reducing the capacity of the cue constellation to discriminate among possible to-be-remembered targets. In the first experiment, this was demonstrated by calling upon geometric shapes as cues and non-words as targets. In the second experiment, the findings were generalised to more concrete and familiar items by calling upon first names as targets and words describing personal characteristics as cues. In Experiment 3, a new cue combination was introduced; this involved two shared cues which together uniquely specified one of the target items although each shared cue was also associated with another item. As predicted by the memory-as-discrimination view, this proved to be the slowest and least accurate of the tested conditions. Finally, Experiment 4 called upon a much easier, concrete task, where only two cues were associated with each of three targets. This meant that in both the one-unique-plus-one-shared and the two-unique cue conditions, all the cues present during learning were presented at test. The findings of this last experiment showed that providing all the possible cueing information could be less effective than a partial cue if the former involved introducing elements that increased the number of targets linked to the cues. All these results concur to support the predictions of the memory-as-discrimination view.

One difference between the studies reported here and previous work is that in the past, cue overload and encoding-retrieval match studies have relied on accuracy rather than response time as a measure of performance. Also, Nairne’s (2001, 2002, 2006) discussion of the memory as discrimination view has generally been in terms of probability of correct recall. However, as our objective was to examine the factors that affect retrieval and to eliminate any potential encoding differences between conditions, RT was the measure of choice. We have made the general assumption that difficulty in retrieving a target can be expressed in the time necessary to respond in a cued recognition task. In effect, the assumption was that competition among retrieval targets would lead to a measurable delay in responding. We would argue that this is a reasonable assumption. As mentioned in the introduction, it is very similar to the one made in research on the fan effect (Anderson, 1974; Anderson & Reder, 1999) showing that when more facts are known about a concept, the time to retrieve a fact about the concept slows.

After comparing the temporal properties of various episodic retrieval tasks, Nobel and Shiffrin (2001) argued that recognition relies on parallel access to representations allowing relatively fast ‘old’ or ‘new’ responses, based on computed familiarity. These authors suggest further that the temporal dynamics of cued recall have the hallmarks of a more sequential memory search process that involves successive sampling and recovery until the relevant representation of the target is found (or the search is terminated). This idea of a relatively slow sampling and recovery process is certainly compatible with a) the average response times reported here b) the sizable slowing associated with the one-unique and one-shared condition relative to the one-unique condition (200 to 300 msec approximately on average, depending on the experiment) and c) the idea that cues that are not discriminative will tend to inhibit retrieval of correct targets because of competing candidates.

If the findings reported here are taken as supporting the memory-as-discrimination viewpoint, what does this imply for the encoding-retrieval match hypothesis and for the proposals that have relied on this assumption until now? At the very least, we would surmise that the idea that increasing the encoding-retrieval match leads to better recall needs to be systematically associated with a cautionary note. The results presented in the current paper clearly suggest that the capacity of a cue to discriminate between potential retrieval candidates should be considered as a better predictor of performance than straightforward encoding-retrieval match.

This suggestion is related to other views, such as theories of distinctiveness. Hunt (2003, 2005), for example, agrees that one of the defining features of memory retrieval is discrimination: a target memory must be selected and other similar events rejected. He goes on to suggest that distinctiveness has very often been invoked as a means of achieving discriminability. If an event is processed in a distinctive manner, it will easily stand out against the background of similar events that did not benefit from this distinctive processing. Here, distinctiveness has been defined as relating to the interplay between the cueing information, the targets, and the competing retrieval candidates. In that sense, it is a view that situates distinctiveness at the point of retrieval; an item cannot be said to be distinctive unless the cueing information is known and the set of competing candidates can be at least estimated [see Hunt (2006) and Nairne (2006) for a related discussion of distinctiveness effects on memory].

To conclude, in the experiments presented here, less information was better if that information was more diagnostic of the retrieval target. As highlighted by Nairne (2001, 2002, 2005, 2006) , it would appear that an increase in the encoding-retrieval match can have no effect, can support retrieval or hinder performance depending on the relationship between the said increase, the to-be-remembered target and the competitors that are also related to the cues. The findings reported in this paper clearly support the proposal that what determines the effectiveness of a cue can only be determined by considering the cue-target and cue-competitor relationships simultaneously.

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Authors notes

[1] Marie Poirier, Caroline Morin, Kyriaki Koutmeridou, and James Fowler, Memory Research Unit, Psychology Department, School of Social Sciences, City University London, James S. Nairne, Psychological Sciences, Purdue University; Friederike Zimmerman, Department of Psychological Sciences, Birkbeck College, Uiversity College London. Experiment 3 was part of Friederike Zimmerman's Master's thesis, completed while she was visiting the Memory Research Unit of City University. We thank Peter Barr and Angela Ng for their technical assistance and Saira Khan for help in collecting the data for experiment 4. James S. Nairne's contribution to this work was supported, in part, by a Grant from the National Science Foundation (BCS-0843165). Correspondence concerning this article should be addressed to Marie Poirier, E-Mail: M.Poirier@city.ac.uk

Table 1 – Mean accuracy for each of the cueing conditions (standard deviations in brackets) in Experiments 1, 2, 3, and 4.

Cueing Conditions	Experiment 1	Experiment 2	Experiment 3	Experiment 4
One-shared	0.92 (0.12)	0.94 (0.09)	0.97 (0.06)	0.99 (0.04)
One-unique	0.92 (0.09)	0.91 (0.12)	0.98 (0.05)	0.99 (0.02)
One-unique plus One-shared	0.93 (0.13)	0.94 (0.08)	0.97 (0.06)	0.99 (.0.4)
Two-unique	0.97 (0.08)	0.96 (0.08)	--	1.00 (0.00)
One-unique plus Two-shared	--	--	0.98 (0.07)	--
Two-shared	--	--	0.84 (0.16)	--

Table 2 – Mean response times for each of the cueing conditions (standard deviations in brackets) in Experiments 1, 2, 3, and 4.

Cueing Conditions	Experiment 1	Experiment 2	Experiment 3	Experiment 4
One-shared	2.04 (1.31)	1.74 (0.39)	1.72 (0.69)	1.44 (0.61)
One-unique	1.59 (0.64)	1.88 (0.62)	1.44 (0.41)	0.99 (0.23)
One-unique plus One-shared	1.91 (0.84)	2.15 (0.79)	1.55 (0.37)	1.21 (0.38)
Two-unique	1.62 (0.65)	1.83 (0.42)	--	0.90 (0.29)
One-unique plus Two-shared	--	--	1.60 (0.41)	--
Two-shared	--	--	2.52 (1.30)	--

Table 3 – T-tests results comparing mean RT for one-unique-plus-one-shared vs one-shared-plus-one-unique in Experiments 1, 2, 3, and 4

	One-unique-plus-one-shared RT	One-shared-plus-one-unique RT	T value	Significance: p value =
Experiment 1	2.10 (1.19)*	2.03 (0.93)	-0.41	0.69
Experiment 2	2.22 (0.80)	2.27 (1.11)	0.30	0.77
Experiment 3	1.70 (0.52)	1.56 (0.33)	1.44	0.16
Experiment 4	1.22 (0.57)	1.37 (0.72)	-0.83	0.42

* SD in brackets

Table 4. Example of the cues and targets called upon in Experiment 2.

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

Table 5 – Target and cue combinations called upon in Experiment 3.

Target Room name	Shared cue **Bed**	Unique cue **Bookcase**	Shared cue **Sofa**
Plate	Bed A	Bookcase 1	Sofa A
Brain	Bed A	Bookcase 2	Sofa B
Juice	Bed B	Bookcase 3	Sofa A
Earth	Bed B	Bookcase 4	Sofa B

Table 6 – Sample target and cue combinations as called upon in Experiment 4.

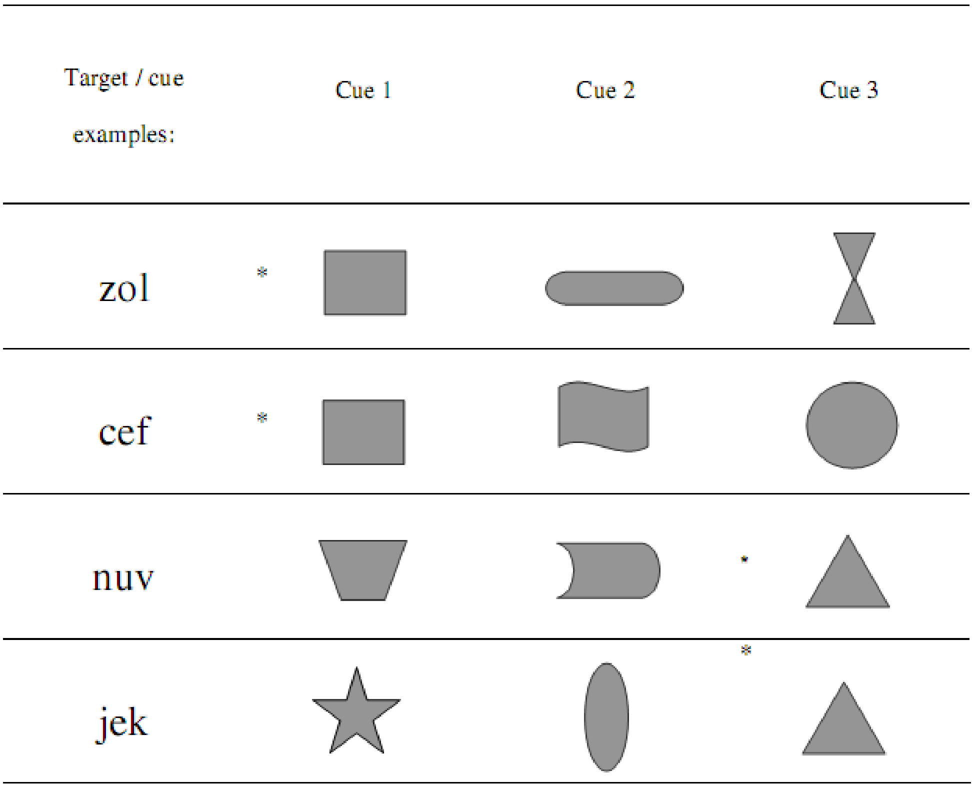
Target	Cue 1	Cue 2
Pig	Pear	Apple
Sheep	Strawberry	Banana
Cow	Grapes	Banana

Figure captions

Figure 1. Example of cue and target combinations called upon in the first experiment; asterisks indicate shared cues [note that in the actual tasks each shape was a different colour].

Figure 2. Illustration of one of the cue-target combinations presented during the learning phase of Experiment 1.

Figure 3. Illustration of the various cue combinations called upon during the testing phase of Experiment 1.


Target / cue examples:
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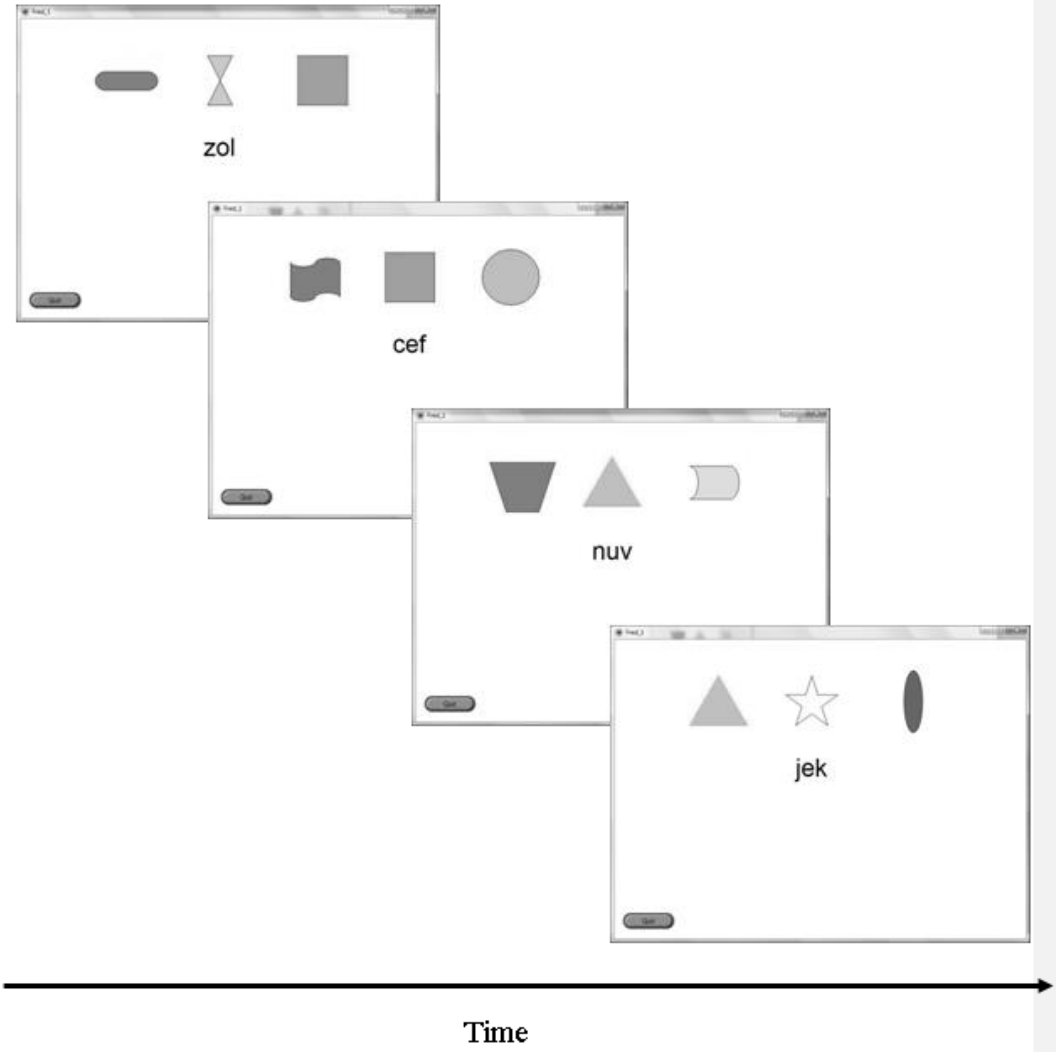
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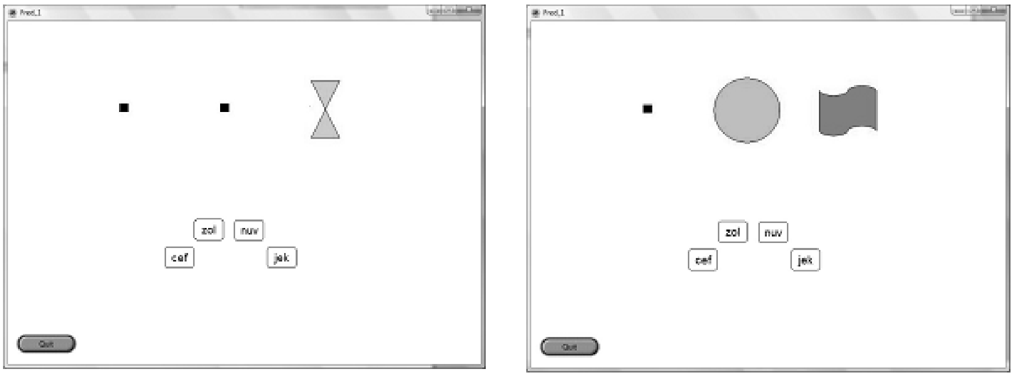
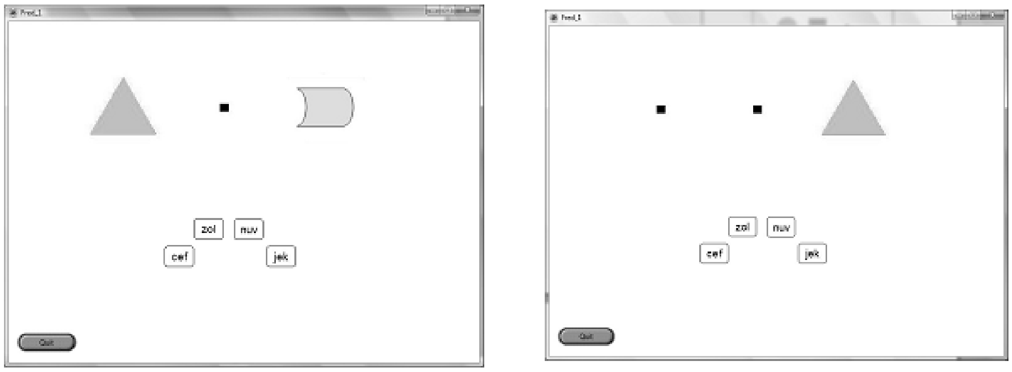


Left panel – one-unique cue example; right panel two-unique cues examples



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