Redintegration and Item Recognition: Effects of Storage Unit Size and Context

BY

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Abstract

Prior research suggests item recognition can involve the redintegration of a storage unit from memory. Evidence for this claim indicates that items from large storage units take longer to recognize than do items from small storage units but only when the study and the test context differ. This evidence, however, offers only limited support because data from storage units larger than word pairs are lacking. Accordingly, two experiments examined whether the interactive effects of storage unit size and context would generalize to the recognition of items from storage units larger than word pairs. In both experiments, participants used interactive mental imagery to organize groups of unrelated words into newly integrated storage units. The number of words within each group varied. In the subsequent item recognition test, a priming technique was used to manipulate test context. In the same context condition, the prime and target came from the same storage unit; in the different context condition, the prime and target came from different storage units. Experiment 1 explored priming effects for storage units that were word pairs, triplets, and quadruplets. The results indicated significant effects of storage unit size and context, but, contrary to expectation, these effects were additive. These results suggested that target processing was the source of the storage unit size effect. Experiment 2 tested this hypothesis further by exploring priming effects for storage units that were pairs and triplets at either a short (400 ms), a medium (1000 ms), or a long (2000 ms) stimulus onset asynchrony. Moreover, in the different context condition the storage unit size for the prime and for the target were combined factorially. Despite these changes, however, the only effect was the additive effect of storage unit size and context, indicating that the processing of the target was indeed the source of the storage unit size effect. The results support the conclusion that recognition of an item can involve the redintegration of a storage unit from memory, but that it is only the item, as opposed to a context item, that initiates the redintegration.

Acknowledgements

Writing this thesis was a difficult task for me. So much so that there were times when I preferred scrubbing the porcelain in the bathroom to writing. Unlike the porcelain, the writing never seemed to end, and the drafts I produced always seemed to be lack-lustre.

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M. K. H.

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Introduction

Isn't it strange . . . ? . . . how a certain taste, or even a smell, can suddenly bring to mind the name of a forgotten friend, or a season of the year, or the happy memory of a past event, or remind us of something forgotten to do.—Eduardo de Filippo

REDINTEGRATION AND MEMORY RETRIEVAL

Sometimes people can return a memory to consciousness by perceiving only a fragment of the original experience. This means that human memory can be redintegrative and some consider redintegration to be an important property of memory retrieval (e.g., Begg, 1982, 1983; Graf & Schacter, 1989; Haist, Shimamura, & Squire 1992; Horowitz & Manelis, 1972; Horowitz & Prytulak, 1969; Masson & MacLeod, 1992; Murdock, 1993; Paivio, 1986, 1991; Weber & Murdock, 1989). This is particularly so when considering the retrieval of integrated materials such as words and idioms (e.g., Horowitz & Manelis; Horowitz & Prytulak), and word pairs integrated by mental imagery (e.g., Begg, 1982, 1983; Paivio, 1986, 1991).

In the current memory literature, two areas of research point to the theoretical importance of redintegration as a retrieval concept. The first area has dealt with issues related to implicit memory—the unintentional use of memory (Schacter, 1987). Researchers in that area have used redintegration to describe the retrieval process when completing words from letter fragments (Graf & Schacter, 1989; Weber & Murdock, 1989) and identifying visually degraded words (Masson & MacLeod, 1992).

The second area of research has dealt more broadly with issues related to mental imagery (Begg, 1982, 1983; Begg & Azzarello, 1988; Paivio, 1986, 1991; Paivio, Clark, & Khan, 1988; Paivio, Walsh, & Bons, 1994; Sharpe & Markham, 1992). In dual coding theory, for example, the redintegrative property of retrieval cues is essential to explaining stimulus-imagery effects in standard paired-associate learning (Paivio, 1986, 1991). Similarly, in the organization-redintegration account of imagery instruction effects, redintegration from a retrieval cue is central (Begg, 1982, 1983; Begg & Azzarello; Begg & Nicholson, 1994; Begg & Sikich, 1984; Desrochers & Begg, 1987).

Despite the theoretical importance of redintegration in these areas, it seems that researchers have paid little, if any, attention to redintegration in other areas of memory research. A few exceptions, however, have occurred in the research on recognition memory. The first was a study by Winograd, Karchmer, and Russell (1971) that examined the effects of imagery and associative instructions in a cued recognition memory task. In the study phase of this task, the participants used either a mental image (the imagery instruction group) or an association (the associative instruction group) to combine the members of A-B word pairs. The A member of each pair was a cue word and the B member was a target word. The participants then received a recognition test for the B target words. In one test condition, the participants viewed the B target words alone. In the other test condition, the participants viewed the B target words along with the A cue word. The results showed a cueing effect—better recognition of target words in the presence of cue words—following study with imagery instructions but not with associative instructions. The interpretation of this effect was that imagery instructions produced unitized storage units in memory that required redintegration at the time of test.

A second example was found in the work of Jacoby, Craik, and Begg (1979). Their research was concerned mainly with establishing distinctiveness of encoding as an explanation of the effects of decision difficulty on memory. In that work Jacoby et al. discussed the importance of distinctiveness for recognition and made the general point that recognition memory involves an expansion of retrieval processes "to achieve a fuller redintegration of the initial context" (p. 596).

Finally, Halldorson, McIntyre, and Begg (1990) examined the effects of imagery instructions on episodic priming in an item recognition task. Two groups of participants studied unrelated word pairs (e.g., ROCK - GOBLET and RAILROAD - MOTHER). In one group, the separate imagery group, participants formed a separate mental image for each referent in a word pair. In the other group, the interactive imagery group, participants integrated the referents of the words in each pair into the same mental image. At test, a target word (e.g., GOBLET) was either primed by a same-context prime (e.g., ROCK) or unprimed by a different-context prime (e.g., RAILROAD). As one might expect, the results showed a priming effect—faster response times for primed targets as opposed to unprimed targets—for target words studied interactively but not for target words studied separately. The interesting aspect of the data was that the priming effect was the result of a response cost to unprimed targets studied interactively. Responding to these targets took approximately 100-ms longer than for any of the other types of targets, which did not differ from each other. The interpretation of this interaction was that recognition of a target from an interactively studied word pair involved redintegration of the other member of the pair.

Although some researchers acknowledge that redintegration is an important part of understanding the retrieval process in recognition memory, it is very clear from this small collection of studies that researchers have done little, if any, work on the problem of redintegration when recognizing items that belong to integrated storage units. As a consequence, it would also seem that researchers have neglected an important retrieval concept in considering the broader problem of retrieval in item recognition memory (cf. Clark & Gronlund, 1996).

To address this shortcoming, the present research provides some additional work on the problem of redintegration as a component of retrieval in making item recognition judgements. In this regard, the research expanded on the work of Halldorson et al. (1990) by examining episodic priming in an item recognition task. The focus, however, was on the relation between the size of a storage unit in memory and context rather than between imagery instructions and context. Accordingly, the participants in the research used interactive imagery to integrate unrelated groups of concrete nouns into storage units that varied in size before receiving the memory test.

To understand the basic rationale for examining the relation between storage unit size and context, first consider the organizational effects of interactive and separate imagery instructions. According to the organization-redintegration hypothesis (Begg, 1982, 1983), interactive imagery produces fewer but larger storage units than does separate imagery. Consequently, a word pair studied by interactive imagery produces a single storage unit containing two members, whereas the same word pair studied by separate imagery produces two storage units containing one member each.

The implication of this analysis is that the findings from the Halldorson et al. (1990) study allow for the interpretation that it takes longer to redintegrate items from a large than a small storage unit but only when the context is different from the one that was present during study. Unfortunately, the Halldorson et al. data only extend to storage units that were the size of word pairs and so it is unknown whether these effects generalize to larger storage units. Therefore, the main purpose of the research was to determine whether the effects of the Halldorson et al. study would generalize to storage units larger than word pairs, and thus, by extension, provide additional support for the proposal that recognition memory can include redintegration as a component of retrieval.

2

Literature Review

The whole gang, always inseparable, show themselves together.—Locke

REDINTEGRATION

Sometimes the most minute and seemingly insignificant part of our experience can spark a vivid memory for a past event. A melody awakes a pleasant memory of time spent in the company of family and friends. The scent of vanilla brings back a childhood memory of ice-cream stands and milkshakes. An image of the Eiffel Tower stirs the treasured memory of a trip through Europe. Simply put, redintegration means that part of an experience restores a memory for the whole experience.

As is true of many other psychological concepts, philosophers were the first to write about redintegration. Hamilton (1981), for example, commented that redintegration was incidentally expressed in the writing of St. Augustin (345-430); Kantor (1969) drew attention to redintegration in the doctrine of memory written by the German philosopher Christian Wolff; and Paivio (1986) remarked that the concept of redintegration was implicit in the work of the British Associationists Berkeley (1658-1753) and James Mill (1773-1836).

Important in these philosophical writings are the ideas that ultimately shaped the meaning of the term redintegration. Two of these ideas are part-to-whole relationships and the synchronous order of thoughts (i.e., order in space).

The idea of part-to-whole relationships emphasized that perceptual experience is a complex or an integration of component elements, much as a chocolate cake is a complex mixture of ingredients. The idea of synchronous order of thoughts, however, emphasized, in the first place, that objects can exist simultaneously in space, and, in the second place, that the thought of these objects reflects this synchronous order (cf. James Mill, 1981). For example, the sight of a sunset has synchronous order in that it includes a sun, a sky, a horizon, and many other objects, all occurring together in space. Similarly, the thought of a sunset reflects this synchronous order in that it will include, simultaneously, a sun, a sky , a horizon, and other objects.

The melding of these ideas, part-to-whole relationships and synchronous order of thoughts, in a number of philosophical works gave the sense of redintegration. The following excerpt from James Mill's chapter, "Association of Ideas," nicely demonstrates this melding.

> Of those sensations which occurred synchronically, the ideas also spring up synchronically. I have seen a violin, and heard the tones of the violin, synchronically. If I think of the tones of the violin, the visible appearance of the violin at the same time occurs to me. I have seen the sun, and the sky in which it is placed, synchronically. If I think of the one, I think of the other at the same time. (1981, p. 57)

Thus, the sense of redintegration is that the thought of one part of an experience brings along the thought of the whole experience.

It is Sir William Hamilton (1788-1856), however, who takes credit for coining the term redintegration (Drever, 1975; Wertheimer, 1970) and presenting the concept in its modern form. For Hamilton, redintegration was the fundamental law of association, overarching the associative laws of contiguity and similarity, and he defined redintegration as follows: "Those thoughts suggest each other which had previously constituted parts of the same entire or total act of cognition" (1981, p. 61). Thus, with these words, the term redintegration was born.

At the turn of the 20^{th} Century, when experimental psychology was in its infancy, traces of the idea of redintegration began to emerge in several psychological works. Wertheimer (1970), for example, suggested that Wilhelm Wundt's idea of assimilation shares with redintegration an emphasis on part-to-whole relationships. Also placing emphasis on part-to-whole relationships, Horowitz and Prytulak (1969) reviewed research by Müller and Pilzecker (1900), and Meyer (1939), on the *initial reproducing tendency*. Important in this research was the finding that one part of a compound can reinstate the whole compound. Along with this early research, Horowitz and Prytulak also acknowledged the use of the term "redintegrative memory" by Hollingworth (1928); and Schacter, Eich, and Tulving (1978) have described the work of Richard Semon[1] (1923) as presenting a redintegrative view of memory retrieval.

Undoubtedly the early psychological literature contains other references to the idea of redintegration, but like many other notions relevant to cognitive psychology, there is a period of about 30 years where interest in redintegration seemed to disappear and then reappears in the 1960s. One line of research that contributed to this renewed interest culminated in a Psychological Review article by Horowitz and Prytulak (1969) called "Redintegrative Memory." In this article, Horowitz and Prytulak established a criterion for identifying redintegration and examined memory for various kinds of units (e.g., words,

[1] Schacter et al. (1978) point out that Semon's ideas about memory date to 1904.

phrases, and sentences). According to Horowitz and Prytulak, the criterion[2] for redintegration was that the members of a unit tend to be remembered or forgotten together. This tendency for all-or-none memory was nicely illustrated in one experiment where participants learned adjective-noun phrases such as HEAVY CAKE and DRY HAIR. The participants' free recall of these phrases showed that .38 of the phrases were completely recalled, .52 were completely omitted, and only .10 were partially recalled (i.e., only the adjective or the noun from the phrase was recalled). In other experiments, Horowitz and Prytulak reported a similar pattern of recall for words, sentences, and two-digit numbers. Since then other researchers have replicated this all-or-none pattern of recall with adjective-noun phrases (see Begg, 1972; Horowitz & Manelis, 1972), and shown that it also occurs for concrete noun pairs integrated by interactive imagery (see Begg, 1973).

Besides this all-or-none pattern of memory, Horowitz and Prytulak (1969) also revealed a unique property of the materials they deemed as meeting the criterion for redintegration. When they compared free recall to cued recall performance for these materials, they found that the part that was most frequently recalled in free recall was also the best cue in cued recalled. This finding was important for two reasons. First, this finding stood in contrast with the finding in paired-associate learning that the *least* frequently recalled member of a pair in free recall also served as the *most* effective cue in cued

[2] To operationalize this criterion, Horowitz and Prytulak (1969) set an arbitrary threshold of .60 for the conditional probability that participants recall the whole unit, given that some part is recalled (i.e., $p(W_i | A_i)>.60$, where W_i denotes recall of the i^{th} whole unit, and A_i denotes recall of part A from the i^{th} whole unit). In subsequent research, however, Begg (1973) rejected this operationalization of the criterion because it can be met by conditions that are clearly nonredintegrative (e.g., word pairs that contain independent members). Note, however, that Begg's objection was to the operationalization of the criterion as opposed to the criterion itself.

recall. The finding of Horowitz and Prytulak thus distinguished redintegration from other associative memory processes. Second, this finding became the basis for proposing a second criterion for redintegration (see Begg, 1972, 1973) that Paivio (1986, 1991) has called the free-to-cued-recall increment. Importantly, the free-to-cued recall increment became a standard indicator of integrative processes in general and of integrative mental images in particular (Paivio, 1991).

Alongside the work of Horowitz and Prytulak (1969), researchers interested in mental imagery explored associative memory phenomena that implicated the integrative and redintegrative properties of mental images. Paivio (1986) has provided a concise summary of this work and made reference to several detailed reviews (see Denis, 1979; Paivio, 1969, 1971; Richardson, 1980). The general finding in this research was that variables affecting the integration, and subsequently the redintegration, of mental images had predictably robust effects on memory performance. In this regard, researchers (e.g., Epstein, Rock, & Zuckerman, 1960) demonstrated that memory performance was better when the members of picture pairs were shown as interactive conceptual units (e.g., a hand inside a bowl) as opposed to when the members were shown as separate units (e.g., a hand beside a bowl). Later on, Bower (1970) showed a similar effect for word pairs when different groups of participants studied the pairs by either interactive or separate imagery instructions.

Other evidence that implicated the integrative and redintegrative properties of mental images came from studies that examined stimulus-imagery effects (see Paivio, 1969). In these studies stimulus-imagery was defined in terms of the concreteness or image-arousing capacity of the material. Concrete materials were those materials that had *high* image-arousing values (e.g., WHITE HORSE), whereas abstract materials were those materials that had *low* image-arousing values (e.g., BASIC THEORY). Using such materials, pairs showed a memory advantage for the concrete materials, and this effect was identified as a redintegration effect.

Also important in the studies that examined the stimulus-imagery effect was that a hypothesis that assumed redintegration was able to predict their outcome—namely, the conceptual-peg hypothesis (Paivio, 1969). According to this hypothesis, the discrete verbal stimuli of concrete materials, as opposed to abstract materials, arouse mental images that combine into complex images. Subsequently, when a concrete stimulus, as opposed to an abstract stimulus, is presented on a memory test, the stimulus initiates redintegration of the entire image from memory. Participants could then use this redintegrated image as necessary to meet the demands of the memory test. The hypothesis thus predicts that stimulus-imagery is an important factor in determining memory performance.

Finally, a series of studies by Begg (1972, 1973) provided additional evidence implicating the integrative and redintegrative properties of mental images. Similar to the studies by Horowitz and Prytulak (1969), the studies by Begg compared free recall to cued recall performance. In these studies Begg found an increment in performance from free recall to cued recall when experimental conditions supported the construction of integrated mental images, but not otherwise. For example, Begg (1972) showed the free-to-cued-recall increment for concrete adjective-noun phrases but not for abstract adjective-noun phrases, and Begg (1973) showed this increment for concrete noun pairs following study with interactive imagery but not following study with separate imagery. To explain these results, Begg reasoned that (a) redintegration could occur only in those conditions that fostered the construction of integrated mental images, and (b) that cueing in the unintegrated conditions (i.e., study of abstract adjective-noun phrases or study of concrete noun pairs with separate imagery) amounted to the provision of contiguity cues which Bregman (1968) had shown do not increment recall. Consequently, Begg was able to attribute the increment in recall performance to the integrative and redintegrative properties of mental images.

Since the grounding empirical work in the 1960s and early 1970s, researchers have made frequent reference to redintegration. These references are found primarily in the areas of implicit memory and mental imagery.

IMPLICIT MEMORY

The research on implicit memory has been concerned with demonstrating that performance on certain memory tests (e.g., word completion, perceptual identification, lexical decision) is influenced by memory for prior experiences even though people are largely unaware of their memory for those experiences (for reviews see Richardson-Klavehn & Bjork, 1988; Roediger & McDermott, 1993; Schacter, 1987). Experiments that have examined the memory performance of amnesics provide the most dramatic demonstration of this type of memory. In one classic experiment, for example, Warrington and Weiskrantz (1974) showed that when amnesics read a list of words they were more likely to complete fragments of those words (e.g., red__teg__t__n), despite their inability to recognize those words as being read earlier. There are many other demonstrations of these kinds of effects with amnesics and other researchers have shown that similar effects also occur in people with normal memories (e.g., Graf & Schacter, 1985; Roediger & McDermott, 1993).

Although the theoretical and empirical issues surrounding implicit memory phenomena are diverse and complex, it is of interest to note that some researchers working on these issues have incorporated redintegration into their explanations of implicit memory. Graf and Schacter (1989), for example, proposed that unitization (i.e., the representation of separate elements as a single unit) affects implicit memory because unitization enables "the redintegration of studied items in response to partial cues" (p. 930). Similarly, in a context-sensitive account of implicit memory, Masson and MacLeod (1992) stated that "information provided in the retrieval cue (e.g., a word-stem or a briefly flashed word) enables redintegration of the original encoding operations applied during the initial encounter" (p. 147). Finally, Weber and Murdock (1989), and subsequently Murdock (1993), have incorporated redintegration into their mathematical models of memory and applied these models to implicit memory phenomena. It is also of interest to note that the incorporation of redintegration into these explanations of implicit memory is owing to the early work of Horowitz and Prytulak (1969).

Mental Imagery

Dual Coding Theory

The second area of research that has made use of redintegration is the research on mental imagery. Paivio (1986, 1991), for example, has developed a comprehensive theory of memory and cognition known as dual coding theory (DCT). Paivio developed the theory from the conceptual-peg hypothesis of stimulus-imagery effects, and as a result, the theory incorporates the idea of redintegration into its framework.

The most general assumption of dual coding theory is that two independent but related systems handle our experiences. These systems are the verbal and nonverbal systems, respectively. The verbal system deals with language, whereas the nonverbal system (also known as the imagery system) deals with the nonlinguistic experience of objects and events (e.g., the experience of eating a strawberry).

Another assumption dual coding theory is that the verbal and nonverbal systems retain the concrete qualities of experience as defined by sensorimotor modality (i.e., sight, sound, touch, smell, taste, etc.). So, for example, the verbal system retains what the written word STRAWBERRY looks and sounds like, whereas the nonverbal system retains what a strawberry looks and tastes like.

Although both systems retain the various sensorimotor qualities of experience, the theory proposes that each system works with its own kind of unit to represent these qualities. The verbal system works with verbal codes or logogens (word generators) and these codes mirror the discrete and sequential organization of language. Sentences, for example, are a concatenation of words and reading them occurs in serial order. The nonverbal system, on the other hand, works with nonverbal codes or imagens (image generators) and these codes mirror the continuous and synchronous organization characteristic of visual images[3]. This continuous and synchronous organization emphasizes that, while imagens represent parts, the boundaries between parts are indefinite and the experience of those parts is usually integral with some larger unit. For example, the usual visual experience of a nose is as an integral part of a face (which simultaneously

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[3] A common misconception of dual coding theory is that it contrasts the verbal system with the visual system. It is important, therefore, to recognize that a visual image is just one kind of image that the nonverbal system handles. The nonverbal system also handles images corresponding to the other sensory modalities such as the auditory, gustatory, and olfactory modalities. Paivio (1986, 1991) provides a more thorough discussion of this point.

includes a mouth, eyes, ears and so on), and this experience can expand and shift without interruption to any portion of the face. An important implication of this continuous and synchronous organization is that "part of an image usually redintegrates the whole" (Clark & Paivio, 1987, p. 7).

Organization-Redintegration

Another theory that grew out of earlier research on mental imagery and incorporates redintegration into its framework is the organization-redintegration hypothesis (Begg, 1982, 1983). This hypothesis accounts for the effects of imagery instructions on memory, most notably the effects of interactive and separate imagery. The significance of this hypothesis is that it provided the main impetus for the research at hand.

Encoding

Imagery instructions. Imagery is one of many different ways to encode or put information into memory. For example, the word BALL can be encoded by counting the number of letters it has, by rating its pleasantness, or by using the mind's eye to imagine a picture of a particular kind of ball, such as a baseball.

Just as there are different ways to encode information, there are different ways to use imagery for encoding (Begg, 1982, 1983). Interactive and separate imagery are two of these different ways to use imagery. To illustrate the difference between them, consider the word pair BAT-BALL. Separate imagery would involve forming two separate images, one for BAT and one for BALL. Interactive imagery would involve taking the separate images of BAT and BALL and forming them into a single, integrated image by having them interact. A familiar interactive image would be a bat striking a baseball or a more bizarre image might be a baseball that has sprouted bat wings flying through the air.

Imagery instructions and memory organization. Imagery instructions can influence the organization of storage units in memory (Begg, 1982, 1983). An important aspect of this organization concerns the number of members retained within a storage unit. Separate imagery instructions, for example, result in relatively simple storage units that retain only one member. Interactive imagery instructions, on the other hand, result in more complex storage units that can retain two or more members.

Memory Retrieval

Broadly defined, memory retrieval is the process of getting information out of memory. From the perspective of the organization-redintegration hypothesis, memory retrieval is a staged process (Begg, 1982, 1983). The first stage is *contact* in which a retrieval cue locates, through a process of discrimination, a storage unit in memory. *Redintegration*, the second stage, then follows and renders all the information contained within the contacted storage unit ready for use. Thus, just like dual coding theory, the organization-redintegration hypothesis proposes that one member of an integrated memory unit can act as a retrieval cue for the remaining members in the unit.

Recognition Memory

Outside these areas of research, implicit memory and mental imagery, researchers have made few references to the idea of redintegration. Some exceptions do occur, however, in the research on recognition memory[4]. First, Winograd et al. (1971) have used redintegration to explain the effects of

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[4] It is of historical interest to note that over 250 years ago Wolff used the notion of redintegration in an explanation of recognition memory (see Kantor, 1969).

interactive imagery instructions on the recognition of targets taken from noun-noun pairs. Second, Jacoby et al. (1979) have commented that recognition typically includes an expansion of retrieval processes "to achieve a fuller redintegration of the initial context" (p. 596). Finally, Halldorson et al. (1990) have used redintegration to account for the effects of imagery instructions on episodic priming in an item recognition task.

Although these researchers acknowledge that redintegration is an important part of understanding the retrieval process in recognition memory, it is very clear from this small collection of studies that researchers have done little, if any, work on the problem of redintegration in the recognition of items belonging to integrated storage units. As a consequence, it would also seem that researchers have neglected an important retrieval concept in considering the broader problem of retrieval in item recognition memory (cf. Clark & Gronlund, 1996).

THE RETRIEVAL PROBLEM IN RECOGNITION MEMORY

There are many different proposals about how people retrieve information from memory. When considering recognition memory there are two basic types of proposals. One type of proposal, generally known as global matching, asserts that recognition involves only a relatively simple matching operation (Dosher & Rosedale, 1997; Gillund & Shiffrin, 1984; Humphreys & Bain, 1991; Humphreys, Bain, & Pike, 1989; Mulligan & Hirshman, 1995; Murdock, 1982). According to this proposal, people match a recognition test probe (e.g., a word), in parallel, against the contents of memory (e.g., all the words stored in memory from a previously studied list of words) and then assess its familiarity or strength.

The global matching proposal contrasts with a second proposal that maintains recognition memory can involve more than a simple matching operation (Clark & Gronlund, 1996; Hintzman & Curran, 1994; Horton, Pavalick, & Moulin-Julian, 1993; Jacoby, 1991; Mandler, 1980; Smith & Halgren, 1989; Tulving, 1982, 1983; Yonelinas, 1994; Yonelinas & Jacoby, 1994). According to this second proposal, recognition of a test probe also includes retrieval processes that are similar to those found in support of recall from memory. These recall-like retrieval processes use the test probe as a cue to recover specific information from memory (e.g., another word on a study list related to the test probe) that can assist in making the recognition judgement (Clark & Gronlund; Hintzman & Curran; Hintzman, Curran, & Oppy, 1992; Jacoby; Nelson, Schreiber, & McEvoy, 1992; Slack, 1983; Yonelinas; Yonelinas & Jacoby).

At issue between the proponents of these two proposals is the necessity to include recall-like retrieval processes in accounting for recognition memory phenomena. Clark and Gronlund (1996) have reviewed much of the evidence on this issue and point to the success of the global matching proposal in handling a wide array of findings. Some of these successes include list-length effects, recognition performance decreases with increases in the length of a study list (Gillund & Shiffrin, 1984; Murdock, 1982); global similarity effects, recognition performance decreases when a test probe is similar but not identical to many items on a study list (Hintzman, 1986); and verbal context effects, recognition of a probe that is a member of a word pair is recognized more accurately and quickly when the other member of the pair is present at test (Clark & Shiffrin, 1992; Dosher & Rosedale, 1989; Murdock, 1982; Ratcliff & McKoon, 1988).

Despite these successes, however, Clark and Gronlund (1996) went on to present a case for recall-like processes in accounting for recognition memory. First, they indicated that, while global matching neatly accommodates many findings, these findings are also compatible with the notion of recall-like processes in recognition, and therefore, there is no compelling evidence to discount the operation of these processes in recognition. Second, they reviewed findings that are at odds with expectations from a global matching view. For instance, global matching predicts a list-strength effect for recognition (strengthening some items on a study list decreases memory performance for the remaining items on a list), but none occurs (Ratcliff, Clark, & Shiffrin, 1990). Additionally, they cited problems in accounting for certain aspects of list-length effects (e.g., Gronlund & Elam, 1994) and global similarity effects (e.g., Hintzman, Curran, & Oppy, 1992) that are perhaps better dealt with by acknowledging some role for recall-like processes.

Finally, Clark and Gronlund (1996) reviewed specific evidence in support of recall-like processes in item recognition memory. This review included evidence from studies that used a process-dissociation procedure (Jacoby, 1991). These studies have shown that, as list length increases, estimates of processes similar to matching remain constant while estimates of recall-like processes decrease (Yonelinas, 1994; Yonelinas & Jacoby, 1994); and included a study by Hintzman and Curran (1994) showing that, early on in the time course of retrieval, matching led to false recognition of lures that were similar to words on a study list, but that recall-like processes counteract this false recognition later on in the time course.

Besides the evidence offered by Clark and Gronlund (1996), Nelson et al. (1992) also reviewed evidence in support of recall-like processes in recognition.

Their review included findings that show better recognition for probes from small than large categories when the recognition test contains lures from studied categories (e.g., study TIGER and test with LION). Presumably this result occurs because participants recall the related category instance from the study list (i.e., TIGER) and use it to reject the lure (i.e., LION), but that this process is more likely to be successful for small than for large categories.

Other evidence comes from a pair of experiments by Johnston, Dark, and Jacoby (1985). These researchers examined perceptual fluency[5] (i.e., the latency to identify a word by naming) as a basis for recognition memory. According to these researchers, if perceptual fluency is the only basis for recognition, then test probes that the participants falsely recognize ought to show greater perceptual fluency (i.e., shorter identification latencies) than those test probes that the participants fail to recognize. Contrary to this expectation the results of the first experiment showed that perceptual fluency for false recognition was less (i.e., longer identification latencies) than for failed recognition, suggesting that a factor other than perceptual fluency was at work.

Johnston et al. (1985) hypothesized that this additional factor was a recall-like retrieval process and tested this hypothesis in a second experiment by disrupting the effectiveness of the recall-like process. To disrupt the recall-like process, they switched the letters in some words on the study list to produce pronounceable nonwords, and thus forced participants to rely more heavily on perceptual fluency. Johnston et al. found that this manipulation reversed the

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[5] Poldrack and Logan (1997) have questioned the merit of defining perceptual fluency in terms of response latency by showing that latency can account for only a small proportion of recognition memory performance. Despite this result, however, I have chosen to include the Johnston et al. (1985) study because there is (a) an important literature on fluency and recognition that has used the latency definition of fluency, and (b) a compelling logic to the study that supports my argument.

effects found in the first experiment; now perceptual fluency was greater for false recognition than for failed recognition.

Another argument supporting the proposal for recall-like retrieval processes is the claim that memory tasks, including recognition memory tasks, are seldom process-pure (Jacoby, 1991). This means that it is very rare that only a single process contributes to the results of any given memory experiment. Since the matching proposal attributes recognition memory performance to a single process, it would seem that the matching proposal also requires the assumption that recognition memory tasks are process-pure. But since this assumption is highly restrictive (because it is rarely met), it seems unlikely that matching is the only process to consider as contributing to item recognition memory. Consequently, other processes, including recall-like retrieval processes, also deserve careful consideration.

In summary, the retrieval problem in recognition memory concerns a debate over whether recall-like retrieval processes are necessary to account for recognition memory performance. Proponents of a single process view argue that recall-like processes are unnecessary and they point to the many successes in using a single processing component to account for a wide variety of recognition memory phenomena. Proponents who argue for the inclusion of a recall-like retrieval process in recognition, on the other hand, acknowledge the importance of the single process view, but they also point out that the evidence in support of that view is also compatible with the view that adds a recall-like retrieval process. Proponents of recall-like processes in recognition then go on to argue that some experimental findings are difficult for the single process view to accommodate and that there are experimental findings to support the inclusion of recall-like retrieval processes in accounts of recognition memory performance. To the foregoing one can add the argument that the single process view requires the strong assumption that recognition memory tasks are process-pure; an assumption that is rarely met in practice.

REDINTEGRATION AS A RECALL-LIKE RETRIEVAL PROCESS

Recall and Information Recovery

Recall suggests deliberate retrieval of information from memory and consists of many different subprocesses (Begg, 1982, 1983; Clark & Gronlund, 1996; Gillund & Shiffrin, 1984; Jacoby, 1991; Mandler, 1980, 1991; Mensink & Raajimakers, 1988; Nelson, LaLomia, & Canas, 1991; Nelson et al. 1992; Paivio, 1986, 1991; Raajimakers & Shiffrin, 1981; Yonelinas, 1994; Yonelinas & Jacoby, 1994). As with other forms of remembering, a retrieval cue sets these subprocesses in motion, and this cue, along with information stored in memory, serves to guide and constrain the retrieval process (Hunt & Smith, 1996; Lockhart, Craik, and Jacoby, 1976; Tulving, 1982, 1983). Whether a retrieval cue is general (e.g., "Write down all the words from the list that you can remember"), or specific (e.g., "Write down the word that was paired with ROCK"), the objective behind any act of recall is to recover the information from memory that a retrieval cue designates.

A variety of different subprocesses can fulfill this objective of information recovery in recall. Perhaps the most well known of these is search and sampling (e.g., Gillund & Shiffrin, 1984; Mensink & Raajimakers, 1988; Nelson, et al., 1991; Nelson et al., 1992; Raajimakers & Shiffrin, 1981). This process is similar in many respects to rummaging through a junk-box in search of an object. The search component is like a systematic plan for locating objects in the box. The sampling component is like inspecting an object for a set of desired characteristics. Importantly, however, just as locating and inspecting an object results in the recovery of an object from the box, search and sampling results in the recovery of information from memory.

Information recovery need not be restricted to a process of search and sampling. The process of information recovery can also be reconstructive (Lockhart et al., 1976) or constructive as Tulving (1982, 1983) prefers. According to this perspective, information recovery is not so much a matter of location and inspection, but rather a matter of combining several sources of information, information in the retrieval cue with information in memory, to approximate the original experience (Anderson, 1995; Zechmeister & Nyberg, 1982). Since information in the retrieval cue or information in memory can bias this approximation, classic examples of this type of information recovery are the distortions in memory that can occur when retelling a story (e.g., Bartlett, 1932) or when providing an eyewitness report (e.g., Loftus & Palmer, 1974).

The process of information recovery in recall can also take the form of redintegration (e.g., Begg, 1982, 1983; Horowitz & Manelis, 1972; Horowitz & Prytulak, 1969; Paivio, 1986, 1991; Schacter, Eich, & Tulving, 1978; Tulving, 1983). Redintegration, like other forms of information recovery, suggests deliberate retrieval and that a retrieval cue starts and guides the retrieval process. Two defining characteristics distinguish redintegration from other forms of information recovery. First, redintegration focuses on the relationship between a part and its whole, the part serving as a retrieval cue to recover a whole complex of integrated information from memory (e.g., thinking of the sun includes the idea of the sky). In this sense, redintegration is similar to the reconstructionist/constructionist view of information recovery; both the information in a retrieval cue and information in memory contribute to the process of information recovery. Redintegration, however, suggests a more complete and faithful reproduction of the original information complex; the resulting information is *not* made to fit with the information that is available to guide the retrieval process. Second, redintegration is defined as synchronous—the parts of a whole information complex stored in memory arrive together in time (e.g., the elements of a face are seen together). Even though this synchronous recovery of information can be probabilistic (cf., Paivio, 1986), this notion suggests that information recovery by redintegration is direct, meaning that redintegration operates only on a particular storage unit in memory. This notion contrasts with the search and sampling view. That view suggests information recovery goes through a series of processing cycles where recovery of the requisite information can involve several different storage units in memory.

Recall-Like Retrieval Processes in Recognition

Proposals that refer to recall-like retrieval processes in recognition can refer to any of the several different subprocesses that characterize recall (e.g., Clark & Gronlund, 1996; Halldorson et al., 1990; Hintzman & Curran 1994; Jacoby, 1991; Johnston, et al., 1985; Mandler, 1980, 1991; Winograd et al., 1971; Yonelinas, 1994). The qualification of "recall-like" acknowledges, first, that recognition does not necessarily include all of the subprocesses that characterize recall (Clark & Gronlund, 1996); second, that retrieval cues for recognition and recall differ in information content (Tulving, 1982, 1983); and third, that the process of information recovery in recognition serves a different objective than in recall (Anderson & Bower, 1973; Fisher, 1979; Jacoby; Lockhart et al., 1976).

Despite these qualifications, recognition is like recall in that there are a variety of subprocesses that can fulfill the objective of information recovery in recognition. Just as in recall, there is reference to search and sampling (cf., Clark & Gronlund, 1996; Johnston, et al., 1985; Nelson et al., 1992), to reconstruction (cf., Lockhart et al., 1976), to construction (cf., Tulving, 1982, 1983), and to redintegration (cf., Halldorson et al., 1990; Jacoby et al., 1979; Winograd et al., 1971).

Thus, the proposal that recognition memory can include redintegration as a component of retrieval is in line with the more general position that there are recall-like processes in recognition. Redintegration, like recall processes, suggests that retrieval is deliberate, that retrieval cues set the retrieval process in motion, and that redintegration fulfills the function of information recovery. Unlike recall processes, however, redintegration suggests a very different process for information recovery and, therefore, this proposal complements existing proposals for recall-like processes in recognition.

The Contribution of Redintegration to Recognition Memory

To this point the argument in favour of redintegration as a component of the retrieval process in item recognition is simply that (a) researchers have neglected, for the most part, to consider redintegration when thinking about the retrieval problem in recognition memory, and (b) redintegration is consistent with existing proposals that recognition can include recall-like retrieval processes. There are, however, two additional reasons to consider redintegration as a component of the retrieval process when making item recognition judgements. The first reason has to do with the direct role that redintegration can play in establishing an episodic context at the time of retrieval, and the second, related reason has to do with the *indirect* role that the provision of this context can play in allowing the distinctiveness of a test item to emerge at retrieval.

Redintegration Establishes Episodic Context at Retrieval

In a general sense, *context* refers to the host of factors that surround the study of a set of test material. These factors can include external factors such as the temperature, color, and size of a room, as well as internal factors such as mood (e.g., happy or sad) and physical state (e.g., rested or tired) of a person. When the test material consists of words, however, it is also appropriate to include among these factors the other words that accompany a test word as well as the mental images that these words can arouse.

Whether the factors that define a context are external, internal, verbal, or imaginal, they are also global or local in nature. Global factors, such as the color of a room, are stable characteristics that endure during the study of all of the test material. Local factors, on the other hand, are characteristics that endure only during the study of a specific item from the test material. So in a word pair like ROCK - GOBLET, for example, ROCK can provide a local context for the test word GOBLET and vise versa. When the context is of this local nature it is common to refer to the context as *episodic context* to emphasize that the context is specific to a particular time and place. Episodic context that is defined as either verbal or imaginal is the focus of concern here.

Recognition memory performance depends on a high degree of similarity in the episodic context that occurs between study and test (Eysenck, 1979; Fisher, 1979; Jacoby & Craik, 1979; Lockhart et al., 1976; Tulving & Thomson, 1973). Supporting this claim is experimental evidence showing that a change in context between study and test impairs recognition in accuracy (e.g., Light & Carter-Sobell, 1970; Tulving & Thomson; Winograd et al., 1971) and in speed (e.g., Halldorson et al., 1990; McKoon & Ratcliff, 1979; Neely & Durgunoglu; 1985). Any process that aids in establishing the original study context at the time of test will then also have a direct impact on recognition memory performance. Since redintegration has the effect of recovering the information from memory that was present with a test item during its study, redintegration qualifies as one type of process that can aid in establishing the original study context at retrieval. In this way redintegration can make a contribution to recognition memory.

Distinctiveness is Relative to Episodic Context

In general, memory performance also depends on the distinctiveness of the storage units in memory. Distinctiveness here refers to the unique and distinguishing characteristics of the units in memory (Eysenck, 1979; Jacoby & Craik, 1979; Jacoby et al., 1979; Lockhart et al., 1976). Several researchers have proposed that these characteristics are the product of the psychological meaning given to the test material during study, and that this psychological meaning is context-relative (e.g., Begg, 1982). To illustrate this context-relativity of meaning, consider the different senses of the word RECORD in the phrase PLAY A RECORD versus SET A RECORD (from Begg & Clark, 1975). The implication of this context-relative view of meaning is that distinctiveness is also context-relative (Begg; Jacoby & Craik; Jacoby et al.; Hunt & Smith, 1996), meaning that what is distinctive in one context may not necessarily be distinctive in another context. Take for example the word pairs BEER - DOG and BEER - WINE (from Begg, 1978). The characteristic ALCOHOLIC BEVERAGE is distinctive for BEER in the context of DOG but not for BEER in the context of WINE.

Redintegration Indirectly Supports Distinctiveness during Retrieval

Regarding recognition memory, distinctiveness can facilitate performance because distinctive storage units are highly discriminable from each other (Eysenck, 1979; Jacoby & Craik, 1979; Jacoby et al., 1979; Lockhart et al., 1976). Establishing the original study context at the time of test is critically important because distinctiveness is context-relative. As a consequence, redintegration can make another type of contribution to recognition memory. This time redintegration plays an indirect role by supporting the episodic context that allows the distinctiveness of a storage unit to emerge during retrieval. This view of the contribution of redintegration to recognition is in keeping with the argument that Hunt and Smith (1996) have made about the contribution of organizational processing to item retrieval, and the proposal by Masson and MacLeod (1992) that redintegration is a critical part of establishing the initial interpretation of an item at test.

EPISODIC PRIMING

Definition

Researchers have commonly used priming to measure the influence of context on a variety of tasks (e.g., Dosher & Rosedale, 1997; McNamara & Diwadkar, 1996; Stolz & Neely, 1995). Priming refers to the finding that, when two words are members of the same storage unit in memory, as compared to when two words are members of different storage units, then the presence of one word (known as a prime) facilitates responding to the second word (known as the target). Priming is episodic when the members of a storage unit are joined by an episodic relation. These are relations that are based on experiences that occur at a specific time and place, such as a memory experiment (Begg & Nicholson, 1994; Dosher & Rosedale, 1991).

Item Recognition

Item recognition is a standard retrieval task used to measure episodic priming (Dosher & Rosedale, 1997). In this task, participants first study a list of words and are then given a memory test. The task set for the participants on this test is to distinguish between "old" and "new" test words. The amount of time it takes to make this judgement and its accuracy are recorded.

Episodic priming is measured in this task by comparing the speed of recognizing the target in two context conditions. The context is manipulated by preceding the test of the target by different types of primes. In the same context condition the prime is from the same storage unit as the target word. In the different context condition the prime is from a different storage unit than the target word. For example, consider the word pairs ROCK-GOBLET, and RAILROAD-MOTHER as two pairs that have been encoded into the memory system. Let the left-hand item of each pair serve as the prime and the right-hand item of each pair serve as the target. In the same context condition, ROCK would precede GOBLET and RAILROAD would precede MOTHER. In the different context condition ROCK would precede MOTHER and railroad would precede GOBLET. The difference in target identification time between the different context and the same context conditions provides a measure of episodic priming[6]. Episodic priming is a positive value in item recognition and reflects faster identification of targets tested in the same context condition as

6 Smith, MacLeod, Bain, and Hoppe (1989) have made a distinction between list-wide episodic priming and pair-specific episodic priming. List-wide episodic priming refers to target facilitation from primes occurring in a study list as compared to primes that the participants have not studied before. Pair-specific episodic priming, on the other hand, refers to target facilitation from a prime that the participants studied in relation with the target (i.e., the other member of a study pair) as compared to a prime that the participants studied but not in relation with the target (i.e., a member from another study pair). The type of episodic priming examined in this dissertation was similar to pair-specific episodic priming, but since study units include triplets and quadruplets, a more appropriate label for the priming effects reported here is unit-specific episodic priming.

compared to the different context condition. Importantly, some researchers have used episodic priming in this task to index the integration of their materials (e.g., Lorsbach & Worman, 1990; McKoon, 1981; McKoon & Ratcliff, 1979, 1980; McNamara, Halpin, & Hardy, 1992; Rabinowitz, 1986; Ratcliff & McKoon, 1978).

IMAGERY INSTRUCTIONS AND EPISODIC PRIMING

Halldorson et. al. (1990) examined the effects of imagery instructions on episodic priming in an item recognition task. Two groups of participants studied a list of unrelated word pairs (e.g., ROCK- GOBLET and RAILROAD-MOTHER). In one group, the separate imagery group, participants formed a separate mental image for each referent in a word pair. Given the word pair ROCK-GOBLET, for example, the participants would imagine a rock and a goblet but keep each image separate from the other image. In the interactive imagery group participants integrated the referents of the words in each pair into the same mental image. For the ROCK-GOBLET pair, the participants might have formed an integrated image by imagining a rock smashing a goblet. At test, the participants viewed a list of words that contained words from the study list intermixed with words that the participants had not studied (i.e., a set of lures). The participants viewed the words on this test list one at a time and determined whether or not each word was a member of the study list, responding "old" if the word was in the study list and "new" otherwise. A 500 ms response-stimulus interval intervened between the presentation of words on the test list. The critical test manipulation was that a target word from the study list (e.g., GOBLET) was either primed by a same-context prime (e.g., ROCK) or unprimed by a different-context prime (e.g., RAILROAD). As one might expect, the results showed a priming effect—faster response times for primed targets as opposed to unprimed targets—for target words studied interactively but not for target words studied separately. An interesting aspect of the data was that the priming effect was the result of a response cost to unprimed targets studied interactively. Responding to these targets took approximately 100 ms longer than for any of the other types of targets, which did not differ from each other. The interpretation of this interaction was that recognition of a target from an interactively studied word pair involved redintegration of the other member of the pair.

To explain their results, Halldorson et al. (1990) proposed (a) that interactive imagery produces larger storage units in memory than does separate imagery, and (b) that it takes less time to redintegrate these larger units in the same than in the different context condition. The first part of this proposal, that interactive imagery produces larger storage units than separate imagery, is straightforward and follows directly from organization-redintegration theory. The second part of this explanation, that it takes less time to redintegrate larger storage units in the same than the different context condition, is more complex, however, and follows only by considering (a) how the retrieval stages from organization-redintegration theory might map onto the time course for making an item recognition memory judgement, and (b) how storage unit size and context (i.e., the relation between the prime and the target in the test sequence) might affect this time course.

Figure 1 shows one possible mapping of the retrieval stages from organization-redintegration theory onto the time course for making an item recognition judgement. When an item is presented for a recognition memory test, the item acts as a retrieval cue where it first makes contact with a storage unit in memory and then redintegrates all of the information contained

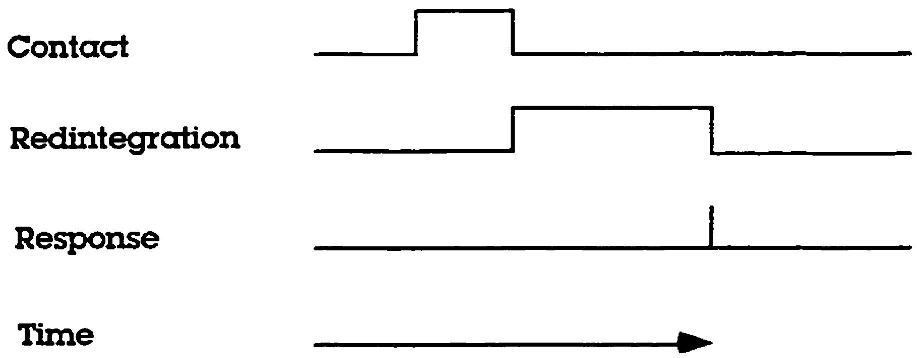

Figure 1. The mapping of retrieval stages from organization-redintegration theory onto the time course for making an item recognition judgement.

within the unit. Each of these stages takes time to complete and has an impact on the amount of time it takes to recognize an item.

In considering how the size of a storage unit might affect the time it takes to complete each stage in the retrieval process, two assumptions are made. The first is that the time to make contact with a storage unit in memory is *unaffected* by its size. Supporting this assumption is research showing that it does not take any longer to contact a large versus a small storage unit in memory (Brannelly, Tehan, & Humphreys, 1989; Conway & Engle, 1994; Wickens, Moody, & Dow, 1981; Wickens, Moody, & Vidulich, 1985). The second assumption is that the time to redintegrate a storage unit from memory is directly related to its size–larger storage units take longer to redintegrate than do smaller storage units. Although there is no direct support for this assumption, this assumption is consistent with the general finding that it takes longer to recover information from large than small retrieval sets, whether these sets are words (Brannelly et al.; Conway & Engle; Heil, Rösler, & Hennighausen, 1994; Jones & Anderson, 1987; Nelson et al., 1991, 1992; Wickens et al., 1981, 1985), sentences (Anderson, 1983; Dosher, 1982; Jones

& Anderson; Reder & Anderson, 1980; Reder & Ross, 1983; Whitow, 1984), or line drawings (Anderson & Paulson, 1978; Heil et al.), and that the time to image to words is related to image complexity, where number of parts in the image defines complexity (Paivio, Clark, Digdon, & Bons, 1989). Thus, the size of the storage unit that contains an item affects the time it takes to recognize the item. The proposal here is that the size of the storage unit does this by influencing the time it takes to complete the redintegration stage of the retrieval process.

At first glance, this proposal may seem to violate the basic definition of redintegration because the proposal seems contrary to the synchronous arrival of information. Upon careful examination, however, it becomes clear that this impression is more apparent than real. To realize this, consider by way of an analogy what the effects of varying a load of cargo might be on the time it takes a tractor-trailer to travel a fixed distance to a destination. Regardless of the load placed on the tractor-trailer, the tractor-trailer and its cargo will always arrive at their destination simultaneously. As the load of the cargo increases, however, the tractor must work harder to bring the cargo to its destination. Consequently, the tractor must use more energy to deliver the cargo and one of the effects of greater energy use can be an increase in the amount of time it takes to deliver the cargo. Increasing the load of cargo increases the amount of time it takes to deliver the cargo, but does not change the simultaneous arrival of the cargo to its destination. The analogy suggests that synchronous arrival of information does not necessarily mean instantaneous arrival of information nor does it necessarily mean information load (as defined by storage unit size) should have no effect on the amount of time it takes for the information to arrive to consciousness.

Although the size of a storage unit containing an item is one factor to consider, another factor to consider is context. In considering the effect of context, Halldorson et al. (1990) presumed that the mapping of the retrieval stages described above (i.e., the contact and redintegration stages in Figure 1) applies to the processing of both primes and targets alike. Figure 2 shows this mapping, and since Halldorson et al. had their participants make recognition judgements on all items in the test sequence, regardless of whether the items were primes or targets, this presumption is reasonable. As Figure 2 shows, when the prime is presented it acts as a retrieval cue, first making contact with a storage unit in memory and then redintegrating the contents of the unit. After the response to the prime and the response-stimulus interval (RSI) elapses, this sequence of events repeats itself when the target is presented. The only difference is that the target now acts as the retrieval cue.

Context can affect the duration of the various retrieval stages when processing the target. When the prime and target are from the same storage unit (i.e., the context is the same), the processing of the prime will speed the processing of the target. This speed-up occurs for two reasons. The first of these reasons is *information relevance*. Presumably, the processing of the prime redintegrates information from a storage unit that is relevant to the subsequent processing of the target, and this information has the effect of reducing, or perhaps even eliminating, the need to redintegrate this information again when processing the target. In other words, the processing of the prime brings along information that is applicable to the processing of the target, and the presence of this information effectively provides a head-start into the

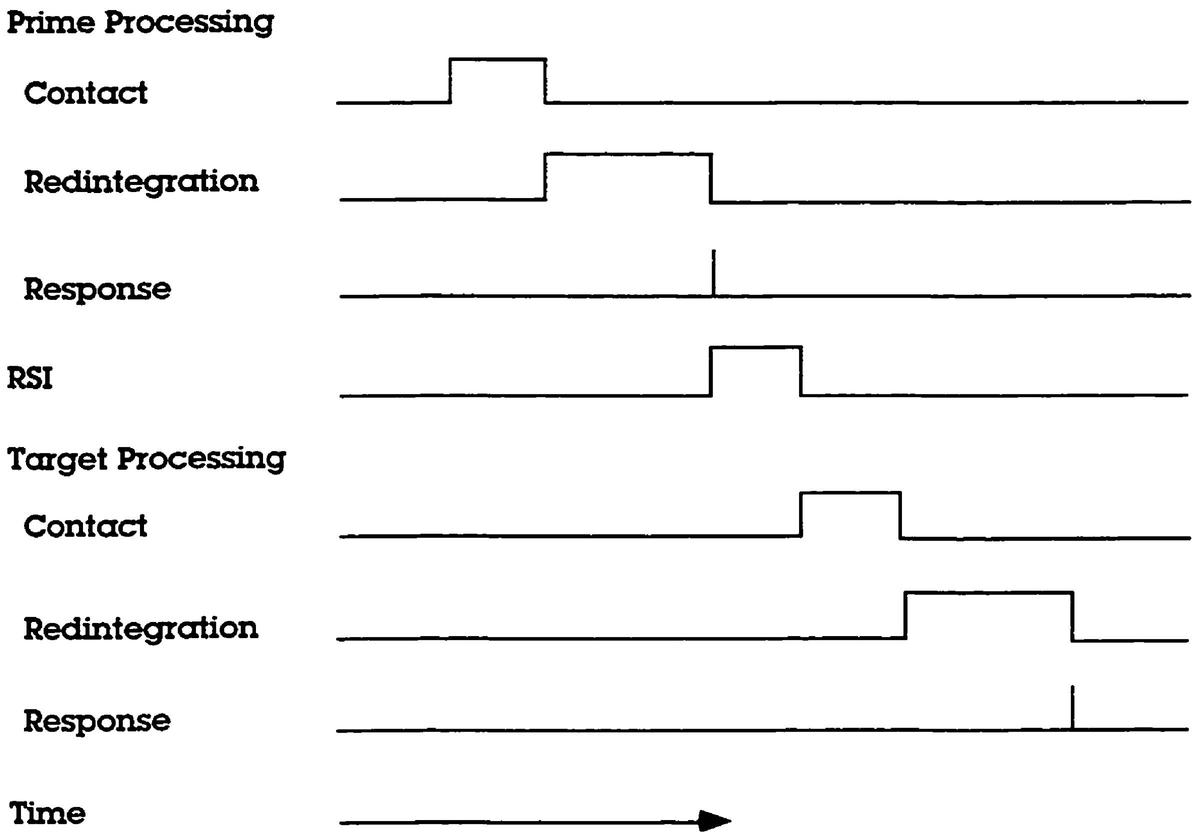

Figure 2. The mapping of retrieval stages from organization-redintegration theory onto the time course for responding in the prime-target test sequence. *RSI* = Response-stimulus interval.

retrieval process by reducing the information load placed on target processing. The second reason for this speed-up in target processing is *repetition of retrieval processes*. Since the stages of retrieval during prime processing operate on the same storage unit in memory as do the stages of retrieval during the subsequent target processing, the target benefits from a repetition of retrieval processes. Consequently, these factors, information relevance and repetition of retrieval processes, work together to reduce the retrieval burden on target processing. This smaller retrieval burden, in turn, shortens the time it takes to carry out the stages of retrieval when processing the target, and hence, speeds target recognition.

The assumptions of information relevance and repetition of processing have considerable support. First, there is a literature on associative priming effects that has consistently shown that information related to a target word (i.e., relevant information) speeds the processing of the target (e.g., Cañas & Bajo, 1994; Dosher & Rosedale, 1997; Lorsbach & Worman, 1990; Masson, 1995; McNamara & Diwadkar, 1996; Neely, 1991; Nelson, et al., 1991; Stolz & Neely, 1995). Second, the effects of practice on response time are well known and many studies have shown that repetition improves retrieval speed in a number of tasks (see Anderson, 1995).

When the prime and target are from different storage units (i.e., the context is different), the processing of the prime will slow the processing of the target. This slow-down occurs primarily because target processing loses the benefits of information relevance and repetition of processing. This loss occurs because the prime directs processing to a storage unit that is *irrelevant* to the subsequent processing of the target. The implication of this loss is that there is *no* head-start into target processing and that contact with the relevant storage unit in memory (i.e., the storage unit containing information about the target) and the redintegration of the information contained in that unit can only begin with the presentation of the target. Put differently, the prime engages a set of retrieval processes that bring along information that is *inapplicable* to the processing of the target. In turn this has the effect of placing the entire burden of retrieval onto the processing of the target. The larger burden lengthens the amount of time it takes to carry out each of the stages in the retrieval process and slows target recognition.

Besides losing the benefits of information relevance and repetition of processing, there is also the possibility that irrelevant information redintegrated by a prime can spill over and interfere with target processing. Evidence supporting this assumption comes from a study by Posner and Snyder (1975) who have shown that irrelevant information from a prime can slow (i.e., inhibit) the processing of a target. Additional supporting evidence comes from studies that have demonstrated that end-of-sentence processing can spill over and interfere with the processing of the first word in the next sentence (e.g., Haberlandt & Graesser, 1985; Just, Carpenter, & Woolley, 1982). Finally, the interference assumption is consistent with the more general proposal that good memory performance depends on the ability to suppress irrelevant information from memory (e.g., Cantor & Engle, 1993; Conway & Engle, 1994; Gerard, Zacks, Hasher, & Radvansky, 1991; Hasher & May, 1997).

To summarize, target recognition benefits from a sharing of the retrieval burden between prime and target in the same context condition but not in the different context condition. This sharing of the retrieval burden speeds the recognition of the target because it reduces the time it takes to carry out the various stages of retrieval. Reduction in processing time occurs because of information relevance and repetition of retrieval processes. Without this sharing of the retrieval burden between prime and target in the different context condition, the processing of the target undertakes the entire burden of retrieval and is subject to interference by irrelevant information. This has the effect of slowing target processing, as compared to the same context condition.

OVERVIEW OF EXPERIMENTS

The implication of the theoretical analysis is that context can offset the effects of storage unit size on response time to targets when the prime redintegrates target relevant information, but can also exaggerate the effects of storage unit size on target response time when the prime redintegrates target irrelevant information. The main hypothesis this line of reasoning suggests, then, is that when both the prime and target are redintegrative, then storage unit size and context should interact so that storage unit size effects are attenuated in the same context condition as compared to the different context condition. In other words, priming effects should increase with an increase in storage unit size.

Although the data from Halldorson et al. (1990) are clearly consistent with this hypothesis, there are a couple of problems[7] with placing too much emphasis on those data. First, the theoretical account of those data was after the fact, and therefore the study does not constitute a test of the hypothesis. Second, the data provide support for the hypothesis over only a very limited range of storage unit sizes—storage unit sizes of one and two to be exact.

In view of these problems, the experiments described herein had two basic purposes. The first was to provide a fresh examination of episodic priming effects in an item recognition task as a function of the size of a storage unit in memory. The second purpose was to isolate the source of any set size effects; that is, are the effects of storage unit size located with the processing of the prime, the processing of the target, or some combination of prime and target processing? Both Experiment 1 and Experiment 2 were designed to meet the first intent, whereas Experiment 2 was designed to meet the second intent.

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[7] One potential problem is that there is an inherent confound in making the storage unit size comparison between separate and interactive imagery instructions. Namely, there are twice as many storage units in the separate imagery instruction condition as there are in the interactive imagery instruction condition. This is so even though the number of members retained in the two conditions are the same. Prior research by Johns (1985), however, has shown that the number of storage units comprising a list does not affect recognition response time. Consequently, this confounding is unimportant and the comparison between separate and interactive imagery is a valid comparison of storage unit size.

The general procedure for each of the two experiments was one that several researchers have employed in the study of both semantic and episodic priming effects (e.g., Neely & Durgunoglu, 1985; McKoon & Ratcliff, 1979). The procedure consisted of a series of study-test trials where the participants first studied a short list of words and then received a test on a sequence of prime-target pairs. On each of these test sequences, the prime was shown to the participant for a brief period of time before the target was presented. The task for the participants was to read the prime word and then make a recognition judgement about the target. Importantly, the test list contained test words that were either old study words or new distractor words, and the participants made old-new discriminations on these words. An important feature of this study-test procedure was that it allowed control over the time interval between the onset of the prime and the onset of the target, or stimulus onset asynchrony (SOA). The SOA feature thus had the desirable characteristic of controlling the amount of time given to prime processing and was important in Experiment 2.

One difference between the procedure used here and that used by other researchers was the nature of the study task assigned to the participants. Whereas other researchers have typically provided participants with general instructions to learn the words in a study list, the participants in the present set of experiments were provided with specific instructions to form the words on the study list into coherent memory units by using interactive imagery.

There were several advantages to using the interactive imagery technique over the use of general study instructions. The first advantage was that the qualitative nature of processing the study material could be expected to be more consistent across participants with interactive imagery instructions than general instructions. The reason for this advantage is simply that participants given general instructions are free to adopt a variety of learning strategies, whereas explicit instructions to use interactive imagery greatly restrict the learning strategy adopted by the participants. By reducing the number of learning strategies there should be a concomitant reduction in the difference between participants in the processing of the study list. The second, and the most important advantage, however, was that the integrative property of interactive imagery permitted systematic variation of the size of the storage units in memory.

A second difference in the procedure was that the participants attended two training sessions before they attended a priming session where item recognition was tested. These training sessions also put the participants through a series of study-test trials and required that the participants learn the study material using the interactive imagery technique. These training sessions employed a cued-recall test of memory rather than an item recognition test of memory. For the cued-recall test, the participants received a word (i.e., a cue) from the study list and recalled the other words that they had studied along with the cue word. Thus, the participants had several sessions of practice at integrating the words on the study lists with interactive imagery and retrieving the words from memory before they received the item recognition test. The purpose of these training sessions was to help ensure that the participants learned and organized the words on the study lists to approximately the same degree (cf. Conway & Engle, 1994).

In summary, the participants attended three separate sessions. The first two of these sessions were training sessions. The third was a priming session that included a test of item recognition memory. All three of these sessions exposed the participants to a series of study-test trials. Each study list on a trial contained a short list of unrelated words arranged into groups. These groups varied in the number of words per group, and the participants formed the words in each group into a coherent memory unit by using interactive imagery. In the training sessions, the participants received a cued-recall test of memory following each study list. In the priming session, however, the test that followed each study list included a sequence of prime-target pairs where the participants first read the prime word and then made an old-new judgement to the target word.

3

Experiment 1†

Experiment!

Make it your motto day and night.—Cole Porter

Experiment 1 examined the response time function relating storage unit size to priming in an item recognition task. Study lists were made from word groups arranged into pairs, triplets, and quadruplets (see the top portion of Table 1). The words within each group were unrelated and the number of words in each group defined the size of a storage unit. Participants integrated the words in each group into a storage unit by combining the referents into an interactive mental image. To examine priming effects, a test list contained a series of test pairs. The presentation of each word in a test pair was sequential. The first word in the sequence was a prime and the second word was a test item. The SOA in this sequence of words was 1 second[8]. The prime was always a word from the study list. The test item, however, was either a target from the study list (e.g., BOWL) or a lure that had never appeared in any study list (e.g., MAIDEN). The words in a test pair that contained a target were from the same storage unit (e.g., MARKET - BOWL), or were from different storage

† This experiment is the third in a series of experiments that were used to refine the method. The first two experiments, despite small differences in procedure and organization of materials, shared the same effects as Experiment 1 reported in this thesis. A brief overview of these experiments is given in Appendix A, along with the results for the recall and target priming data.

8 This SOA was chosen because the average response time to a target was about one second in the Halldorson et al. (1990) study.

units but had the same storage unit size (e.g., ICEBOX - BOWL). Participants were instructed to simply read the prime and then to judge the test item for membership in the study list. The participants judged the test item as "old" when they thought the item was a member of the study list and judged the item as "new" otherwise. Response time and accuracy were measured for each test item. Thus, the experiment measured the response time to recognize targets and manipulated two variables: storage unit size (2, 3, 4) and context (same, different).

HYPOTHESES

First, previous research has shown that primes that come from the same storage unit as the target facilitate recognition decisions as compared to primes that come from a different storage unit than the target (e.g., Dosher & Rosedale, 1997; Lorsbach & Worman, 1990; Halldorson et al., 1990; Johns, 1985). In view of that research, it was hypothesized that:

(1) regardless of the storage unit size, participants would recognize targets faster when the prime came from the same storage unit as the target than when the prime came from a different storage unit (i.e., there would be a main effect of context).

Second, according to the redintegration model depicted in Figure 2, both the prime and the target can redintegrate a storage unit in memory. Keeping in mind the findings of Halldorson et al. (1990) and the theoretical arguments outlined previously, the effects of redintegrating a storage unit on the time to recognize a target can depend on both the size of the storage unit, as well as the context that the prime sets for the test of the target. Those findings showed that, even though larger storage units may take longer to redintegrate than smaller storage units, the effect of storage unit size can be offset by same-context primes that reduce, and perhaps even eliminate, the need to redintegrate the storage unit in the process of recognizing the target. On the basis of those effects, it was hypothesized that:

(2) irrespective of context, the amount of time participants take to recognize a target would increase as the size of the storage unit increased (i.e., there would be an effect of storage unit size), and that

(3) same-context primes would offset the effect of storage unit size as compared to different-context primes so that context would interact with storage unit size (i.e., priming effects would increase as storage unit size increased).

METHOD

Participants

The participants were 40 University of Manitoba undergraduates enrolled in an introductory psychology course. Participants received course credit for their participation and English was their first language. The assignment of participants to groups was random. Four participants' data were discarded because they had poor memory for the words in the study list—they recalled less than 75% of the words from the storage units. This left data from 36 participants for the analyses.

Materials

The stimuli were 231 words distributed among seven trial sets. The trial sets were the basis for the study-test lists in a session. The words for one of these trial sets were nouns selected from several different sources and served in a practice trial. The 198 words for the remaining six trial sets were nouns selected from the norms of Paivio, Yuille, and Madigan (1968) and served in experimental trials. The words from these norms had imagery ratings of six and over, did not exceed 11 letters in length, and were distributed so that the six experimental trial sets were approximately equal on word imagery, word frequency, and word length.

For each trial set, six triples[9] of unrelated[10] words were formed (see Appendix B1). Two words of each triple were primes. These were the same context prime and the different context prime, and were roughly matched for word imagery, word frequency, and word length. The third word of each triple was a target. The same context prime and target were always studied together. The different context prime, on the other hand, was always studied as a member of another study unit. This study unit was always the same size as the study unit containing the same context prime and target. In addition to the six triples, each trial set also included six lure words for the test list, and nine filler words for the study list. Lure words and filler words are shown in Appendix B1 alongside the triples from each trial set.

The word triples within each trial set were further divided into six verbal sets. This was accomplished by randomly assigning word triples to verbal sets with the restriction that only one triple from each trial set could be assigned to a verbal set. In this way, there was exactly one word triple from each trial set in each verbal set. The division of the word triples into verbal sets is also shown in Appendix B1.

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[9] A *triple* and a *triplet* are two distinct elements and should not be confused. A word triple is an element used to facilitate construction of study and test lists. A triplet is an element of a study list that the participants studied.

[10] Unrelated means that words in each triple were considered to be low in preexperimental association. This does not mean that a person can not form associations between the words in the triple. For example, even though a word pair such as CITY-GRASS is low in preexperimental association, a person can still learn an association between the members of this pair easily (McKoon & Ratcliff, 1979).

Procedure

Each participant attended three experimental sessions. The first two sessions were used to train the study lists, whereas the third was used to test item recognition priming. Each of these sessions had two segments. The first segment used a study-test procedure and consisted of six experimental trials, preceded by one practice trial. The second segment consisted of a cued recall test of memory and immediately followed the last trial of the first segment. Sessions lasted approximately 45 minutes.

Up to six participants were tested at one time, and each participant was tested at a separate computer terminal consisting of a keyboard and monochrome video monitor. The computer ran Micro Experimental Laboratory (MEL; Schnieder, 1988) software to control study list presentation in all sessions. The method for test list presentation depended on whether a session was a training session or a priming session. In the training sessions the test lists were presented in booklets. In the priming session the test lists were presented by the computer using MEL software.

Training sessions. A sample trial is shown in Table 1 (see Appendix B2 for a complete set of study lists). On each trial the participants first studied and rated a list of words arranged into study units, and then received a test list that contained cue words for a recall test of memory. The study list consisted of nine study units. Three of these study units were pairs, three were triplets, and three were quadruplets. These study units were displayed one at a time on the computer monitor and the study list went through two presentation cycles. On the first presentation cycle of the list, the display time for each study unit was equal to five seconds for each word in the study unit. This means that pairs were displayed for 10 seconds, triplets for 15 seconds, and quadruplets for

Table 1

Examples of a Study List and a Test List from a Training Session in Experiment 1

Study List		
Pairs	Triplets	Quadruplets
Market-Bowl	Gem-Cell-Student	Hurdle-House-Sunburn-Ship
Frog-Star	Beaver-Morgue-Arrow	Sulphur-Circle-Dirt-Chair
Jury-Icebox	Thorn-Microscope-Abdomen	Engine-Church-Mantle-Dress
Test List		
Market	Student	House
Star	Beaver	Dirt
Jury	Microscope	Engine

20 seconds. On the second presentation cycle, the display time for each word in the study unit was reduced from five seconds to three seconds each. This reduction in display time from the first to the second presentation cycle was in effect only for the first training session, however. The second and third sessions used a three second display time for both presentation cycles of a study list. The order of presentation of the study units on each presentation cycle was random.

Participants were instructed to construct an interactive visual image for each study unit as it was presented (See Appendix C for the training session instructions). They did this by first creating a clear mental image of the referent for each word within the study unit, and then joined them together into a single image by making them interact in some way. For example, the word pair BAT - BALL might be imagined as a baseball bat striking a baseball.

The participants were encouraged to follow several suggestions to help them construct effective images (Higbee, 1988). The first was to make the images vivid by adding as much detail to the image as possible. The second was to be flexible in approach to constructing the images because there were many different ways to interpret the words within a study unit. For example, the word BAT can also refer to a furry mammal that flies. The third, and final, was that an image could be unrealistic as long as it was an interactive image. For example, imagining a baseball that has sprouted bat wings flying through the air is unrealistic but interactive.

Participants were also instructed to provide cohesiveness ratings for each study unit. The task was to rate each image on how well the parts of the image were knit together. A seven-point scale was used for these ratings, with 1 indicating *low cohesiveness* (i.e., the parts of the image were not knit together at all) and 7 indicating *high cohesiveness* (i.e., the parts of the image were knit together very well). The participants indicated their rating by pressing one of the keys 1-7 on the keyboard. The participants were encouraged to use the entire range of numbers on the scale and to use any particular number as often as necessary. The computer drew the rating scale on the computer monitor and allowed the participants five seconds to enter a rating. Upon entering a rating, there was a one second delay and then the computer displayed the next study unit.

After presentation of a study list, the computer program stopped and displayed a message (e.g., "RECALL LIST 1"). At this point, the participants turned to a test booklet to view a test list that contained cue words from the study list. There was one cue randomly selected from each study unit on this test list. Next to each cue, the participants wrote down all the words from the study list that they remembered having been studied along with the cue. For example, suppose that GEM - CELL - STUDENT had been studied together as a unit and that STUDENT was the cue word that appeared on the test list, then the participants would write GEM and CELL in the booklet next to the cue word STUDENT. This test was self-paced and the participants moved on to the next trial by pressing the spacebar on the keyboard.

A final recall test for the words on the study lists followed the last trial in the study-test procedure. For this test, participants were handed a sheet of paper with cue words listed on it. These cue words were randomly selected and one cue word was selected from each study unit. The participants recalled as many words as they could remember as being studied with each cue and wrote those words down on the paper next to the cue. This test was also self-paced.

Priming session. A sample trial is shown in Table 2. Again the participants viewed, studied, and rated a word list arranged into study units, and then received a test list. The study list presentation and the instructions to study and to rate the study units were the same as in the first two training sessions. The test list in this session differed, however. It contained test items for item recognition memory judgements, rather than cues for recall. The participants viewed the test list and responded to test items at the computer terminal.

To accommodate responses to items on the test list, the keyboard at each computer terminal had the "z" and "/" keys labeled as response keys. One key was labeled "Old" while the other was labeled "New". The assignment of these labels to response keys was random for each participant. The spacebar served as a "Ready" button and the participants used it to initiate the study list and test list presentation. The participants pressed the response keys with their left and right index fingers, and pressed the spacebar with one of their thumbs.

Table 2

Examples of a Study List and a Test List from the Priming Session in Experiment 1

Study List		
Pairs	Triplets	Quadruplets
Market-Bowl	Gem-Cell-Student	Hurdle-House-Sunburn-Ship
Frog-Star	Beaver-Morgue-Arrow	Sulphur-Circle-Dirt-Chair
Jury-Icebox	Thorn-Microscope-Abdomen	Engine-Church-Mantle-Dress

Test List			
Context	Prime	Test item	List status of test item
	Storage Unit Size = 2		
Same	Market	Bowl	Target
Different	Jury	Star	Target
	Frog	Blood	Lure
	Icebox	Maiden	Lure
	Storage Unit Size = 3		
Same	Student	Gem	Target
Different	Thorn	Morgue	Target
	Abdomen	Lobster	Lure
	Cell	Mountain	Lure
	Storage Unit Size = 4		
Same	House	Sunburn	Target
Different	Mantle	Chair	Target
	Hurdle	Revolver	Lure
	Circle	Slave	Lure

Note. The storage unit size of a prime defines the storage unit size for a lure since a lure does not have a storage unit size.

The computer signaled the beginning of a test list by displaying the message "PLEASE GET READY FOR THE TEST". This message remained on the computer monitor until the participant pressed the spacebar and initiated the presentation of the test list.

There were 12 test-list pairs in each test list, four pairs for each storage unit size. The first word in each pair was a prime and the second word was a test item. The prime was always a word from the study list. The test item could be either a target word that was also from the study list or a lure word that was not from the study list. The presentation of these pairs occurred in a series of priming trials. The first event on each trial was a fixation point that the computer displayed at the center of the monitor for 500 ms. The prime then replaced the fixation point and the computer displayed the prime for 750 ms. Next, a 250-ms blank interval replaced the prime. The computer then displayed the test item on the monitor and this item remained in view until either the participant made a response or three seconds elapsed. The fixation point, prime, and target displays were at the same location on the computer monitor. There was a 250-ms pause before the presentation of the fixation point for the next trial.

The participants were instructed to read the first word presented on a priming trial (i.e., the prime) but to indicate whether the second word presented (i.e., the test item) was a member of the study list (See Appendix C for the priming session instructions). The participants pressed the response key labeled "Old" to indicate the test item was a target and, consequently, had been a member of the study list; otherwise, they pressed the response key labeled "New" to indicate that the test item was a lure and was not a member of the study list. Participants were also instructed to make their judgements to test items as quickly and accurately as possible. The computer recorded responses that were more than three seconds long as errors.

Again a final test of recall followed the last trial in the study-test procedure. The participants followed the same procedure as they used in previous sessions for this test.

Design[11]

Table 2 shows the six experimental conditions. A factorial arrangement of two factors formed these conditions. These factors were storage unit size (2, 3, 4) and context (same, different). The first factor, storage unit size, was a consequence of targets studied as members of study units that were pairs, triplets, or quadruplets. The second factor, context, was a consequence of targets tested in the presence of primes from the same study units as the targets (same-context primes) or primes from different study units than the targets (different-context primes).

The materials went through two counterbalancing arrangements. The first arrangement was used to permute the targets within each verbal set through the six experimental conditions. To do this, the six verbal sets were combined with the six experimental conditions and six groups of participants in a Latin square. The second counterbalancing arrangement was used to permute each trial set through the six positions in a sequence of study-test trials. This arrangement combined the six trial sets with the six positions in a trial sequence and the six groups of participants in a second Latin square. There were six participants randomly assigned to each group.

These counterbalancing arrangements were coordinated so that the targets within each verbal set would rotate through the six experimental conditions as

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[11] See Appendix D for a schematic of the design.

each trial set rotated through the six positions in the study-test sequence. The first consequence of this was that every participant served in every experimental condition. The second consequence was that every target served in every experimental condition and was viewed at each position in the study-test sequence. The benefit of this arrangement was that position effects could be examined in the data analysis.

The two Latin squares used in this counterbalancing scheme were derived from a standard 6 x 6 Latin square (Cox, 1966). For each of these squares, the rows, columns, and letters of each square were randomly permuted. The squares were then randomly assigned to a counterbalancing arrangement.

The word triples and fillers in a trial set (See Appendix B1) were the basis for constructing the nine study units in a list: three pairs, three triplets, and three quadruplets. Six of these study units were built around kernels that consisted of the same-context prime and the target from each word triple (e.g., STUDENT - GEM). Six fillers were randomly distributed among four of these kernels to produce two of the required triplets and two of the required quadruplets. The remaining three study units were built around the different-context primes (e.g., ENGINE) that were from word triples where the targets were assigned to serve in the different context condition at test. The remaining different-context primes and filler words in the trial set were randomly distributed among these three remaining incomplete study units to produce the required number of pairs, triplets, and quadruplets. This distribution was restricted, however, so that the words within each study unit formed a set of unrelated words.

A test list on each trial consisted of 12 test pairs. Each test pair contained a prime and a test item. Six of these pairs contained a test item that was a target and six pairs contained a test item that was a lure. To construct the test list, the target words were randomly assigned to positions in the test list, and the prime appropriate for the condition preceded each target. The lure words were then randomly assigned to the remaining test-list positions, and were preceded by one of the remaining words from the study list. The selection of these words was random. One restriction on this assignment, however, was that only a word from study units where the target had preceded the lure in the test could be used. Another restriction was that two of these words must be from study units that were pairs, two from study units that were triplets, and two from study units that were quadruplets. This was done to ensure that lures were equally likely to follow primes from each storage unit size.

RESULTS

General

All data analyses exclude the data from the first study-test trial because this trial was a practice trial. Appendix E contains the analysis of variance tables for Experiment 1 and Experiment 2. All statistical tests in the analyses used an alpha level of .05 for significance, unless reported otherwise. Where appropriate, three F ratios are given for a result (see Coleman, 1979). The first of these was F_1. This F ratio tested the generalization of a result to the population of participants. The second of these was F_2 and tested the generalization of the result to the population of items. The third F was a quasi F ratio and it tested the simultaneous generalization of the result to both the participant and item populations.

Depending on the particular analysis, the quasi F was reported as either F'' or its alternative, min F' (see Clark, 1973). Where the analysis provided a mean square (MS) for the interaction between Items x Participants within

Groups (IxPw.G), the F'' ratio was reported. The analyses of the response time and rating data for targets are examples of where the F'' ratio was reported[12]. Where the calculation of $MS_{IxPw.G}$ was problematic because the participants' responses were binomial, then the $\min F'$ was reported (cf. Clark, 1973). The analyses of the cued recall and error rate data are examples where the $\min F'$ was reported. Appendix G gives the equations used to calculate the F'' and $\min F'$ and their respective degrees of freedom.

To resolve logical inconsistencies that can occur from using three different F tests for a given effect, the decision rule for judging an effect as significant was a joint decision rule (see Forster & Dickinson, 1976). According to this rule an effect was significant only when both F_1 and F_2 were significant. The consequence of applying this decision rule was that the quasi F ratio for the test of an effect was not always significant, even though the F_1 and F_2 ratios indicated that the effect was significant. I have reported the tail probability for the quasi F ratio when this occurs.

A set of preliminary results is presented before the results of main interest—the third session results for target priming. The results are presented in this order because it was thought important to first establish that the participants in the study (a) were proficient in memory for the words they had studied, (b) had organized the words into integrated sets that differed in size, and (c) were accurate in responding to the targets in the priming phase of the experiment. The purpose of these preliminary results, then, was to show that the participants were conscientious in carrying out their assigned tasks, and to build a case against claims that the priming results were the

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[12] Appendix F gives the statistical model and expected mean squares for the analysis of the response time data. The appendix also provides a discussion of the assumptions for the analysis.

consequence of ineffective learning during the study phase or inaccurate responding during the test phase.

Preliminary Results

Cohesion ratings. Cohesion ratings were collected for all three sessions, but the data for only the priming session were analyzed. Presumably this measure gave an index of how well the members of a study unit were integrated. In the analysis of these data there were significant differences between the study units in cohesion ratings, $F_1(2, 60) = 28.88$, $MSE = 0.879$; $F_2(2, 60) = 28.04$, $MSE = 0.906$; $F''(2, 120) = 14.50$, $MSE = 1.785$. Scheffé tests, $\alpha = .10$, revealed that the ratings for word pairs ($M = 6.30$) were greater than the ratings for triplets ($M = 6.05$), which in turn were greater than the ratings for quadruplets ($M = 5.81$). Importantly, the overall ratings for the study units were in the high range of the scale. This suggests that the participants perceived the study units to be highly cohesive. No other effects were significant in the analysis.

Cued recall. Two measures of recall are reported. The first measure provides an indication of the proportion of study units retained, whereas the second provides an indication of the size of those units. The first measure, proportion of complete units recalled, was based on the number of study units for which the participants could recall all of the constituent members. The second measure, items-per-unit recall, was based on the number of members correctly recalled from each storage unit. Since one member from the study unit was used as cue, there were n-1 elements to recall from each unit, where n was the size of the unit. Thus, for units of size 2, 3, and 4 the maximum number of items per unit that could be recalled were 1, 2, and 3, respectively.

The analysis of the unit recall data was separate from the analysis of the items-per-unit recall data. An inverse arcsine transformation of the unit recall data preceded the analysis. The items-per-unit recall data were untransformed.

Table 3 shows the untransformed mean proportion of complete units recalled and the mean number of items-per-unit recalled for Experiment 1. The left-hand side of the table contains the proportions for complete units recalled, and the right-hand side of the table contains the mean number of items-per-unit recalled. For each type of recall data, the first, second, and third columns show the statistics for targets from a storage unit of size 2, a storage unit of size 3, and a storage unit of size 4, respectively. The rows of the table show the statistics for each type of recall data from each experimental session within the experiment.

The analysis for the proportion of complete units recalled indicated a significant storage unit size effect, $F_1(2, 60) = 22.34$, MSE = 0.011; $F_2(2, 60) = 22.68$, MSE =0.015; $minF'(2, 120) = 11.25$, and a significant session effect, $F_1(2, 60) = 42.86$, MSE = 0.055; $F_2(2, 60) = 179$, MSE =0.016; $minF'(2, 87) = 34.58$. A significant Storage Unit Size x Session interaction modified both of the main effects, $F_1(4, 120) = 10.56$, MSE = 0.016; $F_2(4, 120) = 22.13$, MSE =0.011; $minF'(4, 213) = 7.15$. No other effects in the analysis were significant.

Scheffé tests, α=.10, applied to the effect of storage unit size showed that each of the three levels of storage unit size differed in the portion of complete units recalled. Apparently, the smaller the study unit, the greater was the proportion of complete units that participants recalled. Scheffé tests, α=.10, applied to the session effect revealed that the proportion of complete units recalled improved significantly with each additional experimental session. Further analysis with Scheffé tests, α=.10, showed this improvement was greater between the first and second session than between the second and

Table 3

Complete Units Recalled and Items-per-Unit Recalled in Experiments 1

	Proportion of Complete Units Recalled			Mean Number of Items-per-unit Recalled		
	Storage Unit Size			Storage Unit Size		
Session	2	3	4	2	3	4
1	.88	.82	.68	.88	1.69	2.26
2	.99	.96	.94	.99	1.93	2.86
3	.99	.99	.97	.99	1.99	2.95

third session. Finally, inspection of Table 3 suggests the source of the Storage Unit Size x Session interaction. The improvement in unit recall between the first and second experimental sessions grew larger as the size of the storage unit increased.

The analysis for the mean number of items-per-unit recalled revealed significant main effects of storage unit size, $\underline{F}_1(2, 60) = 3014$, $\underline{MSE} = 0.058$; $\underline{F}_2(2, 60) = 3613$, $\underline{MSE} = 0.049$; $\underline{minF'}(2, 119) = 1643$, and session, $\underline{F}_1(2, 60) = 31.01$, $\underline{MSE} = 0.233$; $\underline{F}_2(2, 60) = 166$, $\underline{MSE} = 0.044$; $\underline{minF'}(2, 81) = 26.12$. Additionally, the Storage Unit Size x Session interaction was significant, $\underline{F}_1(4, 120) = 29.57$, $\underline{MSE} = 0.054$; $\underline{F}_2(4, 120) = 53.85$, $\underline{MSE} = 0.030$; $\underline{minF'}(4, 221) = 19.09$. No other effects in the analysis were significant.

Post hoc analysis of the storage unit size effect with Scheffé tests, $\underline{\alpha}=.10$, established that the number of items-per-unit recalled increased as the number of items in a storage unit increased. Post hoc analysis of the session effect with Scheffé tests, $\underline{\alpha}=.10$, established that the number of items-per-unit recalled differed between session 1 and session 2, but not between session 2 and session 3. Finally, inspection of Table 3 suggests that the Storage Unit

Size x Session interaction was the result of a greater session effect for units of size 4 and of size 3 than it was for units of size 2.

In summary, the results from the recall data are straightforward. With more practice, the participants were able to recall more study units as well as more items per unit. Although this improvement with practice was greater for large versus small study units, which is not surprising because larger units should be more difficult to learn than smaller units, by the end of the third session the proportion of complete units recalled for each storage unit size was nearly identical. Of equal importance, however, was the item-per-unit recall measure. This measure showed that increasing the size of a study unit was accompanied by an increasing number of items recalled from a study unit, and indicated further that the size of the storage units in memory were near their asymptote. Together these results mean that the participants had thoroughly learned the study material and organized it into storage units that varied in size.

Accuracy. Table 4 shows the proportion of "old" responses to items on the recognition memory test in Experiment 1. The storage unit size for lures in this table was defined by the storage unit size of the prime, since the lures technically did not have a unit size. This table clearly shows that participants were very good at discriminating between "old" and "new" items on the recognition memory test. For each storage unit size, the proportion of "old" responses to targets were well above chance levels ($\underline{M}$ = .96), whereas this same proportion for lures was well below chance levels ($\underline{M}$ = .04). The error data analysis presented with the priming results provides a more detailed analysis of the accuracy data for "old" targets.

Table 4

Proportion of "Old" Responses by Context and Storage Unit Size in Experiment 1

			Storage Unit Size		
Context	Test Item	Correct Response	2	3	4
Different	Target	OLD	.97	.91	.93
Same	Target	OLD	.99	.99	.99
	Lure	NEW	.04	.06	.03

Note. The unit size of a prime defines the unit size for a lure since the lure technically does not have a unit size.

Summary. These preliminary results make three basic points that are relevant to understanding the results for target priming. First, although participants indicated there were some differences in integration, all the study units, regardless of their size, received high cohesiveness ratings indicating that there was substantial integration of the storage units in memory. Second, the recall measures established that memory for the study units was proficient and that the study units were organized into storage units that differed in size. Third, the accuracy data indicated that the participants were conscientious in making their judgements to items in the recognition test phase of the experiment. Thus, the results for the priming data are not likely to be the result of poor learning or sloppy responding.

Priming Results

Target priming. Each participant made responses to 36 "old" target items. For each response, a computer recorded the response time (RT) and the response accuracy. The analysis of the RT data was separate from the analysis of the accuracy data. The RT analysis was for correct responses and estimates of missing data on trials where participants made an error. Estimates of these missing data were based on each participant's mean response time for the condition in which the error occurred. Estimating the missing data was justifiable because the participants made few errors overall (see the accuracy data). The resulting data were then transformed using common logarithms and the analysis was done on these transformed data.

For the accuracy data, the analysis was for the proportion of errors made by each participant in each of the experimental conditions. An inverse sine transformation was carried out on these target error rates before analysis.

All reported Fs and associated MSEs are for the transformed data. The response time data shown in tables and figures, however, are for the transformed data in the units of the original measurement scale[13]. For the response time data these units are in milliseconds (ms). For the accuracy data, however, the data are for the proportions prior to transformation.

Table 5 shows the mean response times, standard errors, and error rates for Experiment 1. The first and second rows present the mean response time, standard error, and error rate for the different and same context conditions, respectively. The left-most portion of Table 5 contains the mean response time, standard error, and error rate for storage unit size 2; the middle portion of Table 5 contains these statistics for storage unit size 3; finally, the right-most portion of Table 5 contains the mean response time, standard error, and error rate for storage unit size 4. Figure 3 depicts the values in Table 5 where it may be easier to see the effects in this study.

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[13] A mean on the transformed scale (M') is converted to the units of the original measurement scale by taking the antilog10(M'). An estimate of the standard error (SE) for the mean in units of the original scale is just the antilog of the mean plus its standard error on the transformed scale minus the antilog of the transformed mean, SE = antilog10(M'+ SE') - antilog10(M').

In the analysis of the target response time data the Context x Storage Unit Size interaction was not significant, (all Fs<1), but there were two main effects. First, there was an effect of context, $F_1(1, 30) = 99.15$, $MSE = 0.037$; $F_2(1, 30) = 240$, $MSE = 0.015$; $F''(1, 51) = 70.56$, $MSE = 0.052$. The responses to same context targets were 112 ms faster than the responses to different context targets. Second, there was a main effect of storage unit size, $F_1(2, 60) = 5.11$, $MSE = 0.022$; $F_2(2, 60) = 3.76$, $MSE = 0.029$; $F''(3, 117) = 2.57$, $MSE = 0.051$, $p<.06$. Follow-up analyses of this effect with Scheffé tests, $\alpha = .10$, indicated a pattern of results where the mean response time for targets from a storage unit size 2 and a storage unit size 3 were significantly faster than from a storage unit size 4, but response time for targets from a storage unit size 2 and a storage unit size 3 did not differ significantly from each other. This means that responses to targets from the two smaller storage units were 37 ms faster on average than were responses to targets from a storage unit size 4.

In this experiment, the overall error rate was 0.04. The participants were more accurate for the same context targets than for the different context targets, $F_1(1, 30) = 16.62$, $MSE = 0.016$; $F_2(1, 30) = 9.92$, $MSE = 0.024$; $minF'(1, 56) = 6.21$. There was also a significant interaction of Context x Storage Unit Size, $F_1(2, 60) = 3.24$, $MSE = 0.009$; $F_2(2, 60) = 4.86$, $MSE = 0.013$; $minF'(2, 115) = 1.94$, $p<.15$. Inspection of the error rates in Table 5 shows that this interaction was the consequence of a smaller context effect for storage unit size 2 targets ($M = 0.02$) than for either storage unit size 3 targets ($M = 0.08$) or storage unit size 4 targets ($M = 0.06$). No other effects in the analysis of the error rate data were significant.

Table 5.

Means and Standard Errors in Milliseconds and Errors (e) for the Context and Storage Unit Size Conditions in Experiment 1

	Storage Unit Size								
	2			3			4		
Context	M	SE	e	M	SE	e	M	SE	e
Different	659	17	.03	685	21	.09	708	20	.07
Same	528	19	.01	518	20	.01	562	19	.01

Lure RTs. Since the lures were not counterbalanced, the analysis of the RT data for lures used a one-way repeated measure design with three levels of prime storage unit size. These data were transformed to common logarithms before analysis. There were no significant effects in the analysis of these data.

DISCUSSION

The results from Experiment 1 clearly support Hypothesis (1). This was not surprising given the findings of other researchers who have shown context effects on a number of different tasks designed to measure episodic priming (Lorsbach & Worman, 1990; Neely & Durgunoglu, 1985; McKoon, 1981; McKoon & Ratcliff, 1979, 1980; McNamara, Halpin, & Hardy, 1992; Rabinowitz, 1986; Ratcliff & McKoon, 1978). Importantly, this finding supports the position that the participants in the study were effective at applying interactive imagery to the word groups appearing on the study list and were able to form newly integrated storage units in memory.

The results also supported Hypothesis (2). The participants responded to the targets from the smaller storage units faster than they did to the targets from the larger storage units. That the participants did not respond differently to the targets from storage units that were of size two and three was

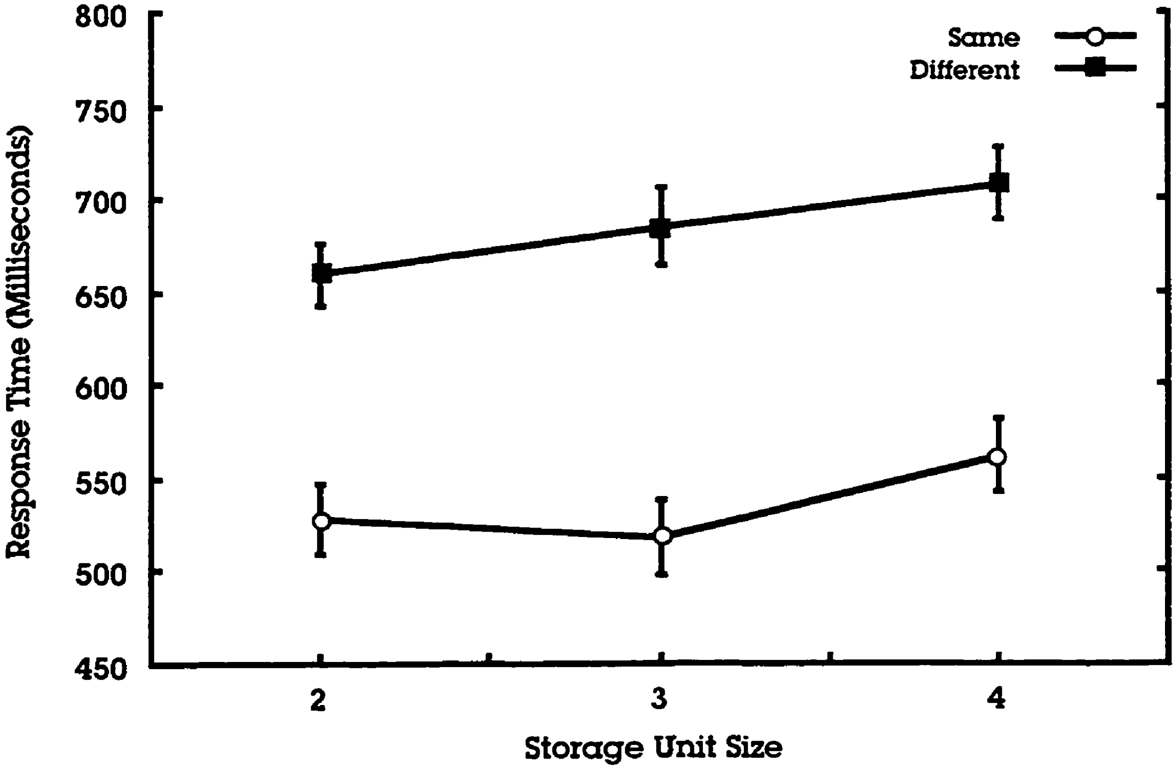

Figure 3. Response time to targets at each storage unit size for the same and different context conditions. In the same context condition the prime and the target came from the same storage unit. In the different context condition the prime and the target came from different storage units. Error bars indicate ±1 standard error of the mean.

inconsequential. As shown in Experiment 1A and Experiment 1B (see Appendix A), and as the following experiment will show, participants respond to targets from a storage unit of size two faster than they do to targets from a storage unit of size three. Certainly, then, there is ample evidence for the idea that response time to a target increases as the size of a storage unit in memory increases. The interpretation of this effect was that it takes more time to redintegrate large than small storage units.

The results, however, did not uphold Hypothesis (3), since the effects of storage unit size and context were clearly additive (i.e., there was no interaction). What this result may represent is a failure in the assumption that both the prime and the target are redintegrative. Presumably, if the same-context prime had redintegrated the storage unit in memory that was relevant to the subsequent processing of the target, then this should have reduced the subsequent retrieval burden placed on the target and attenuated the effects of storage unit size. Moreover, if the different-context prime had redintegrated a storage unit that contained information that was irrelevant to the processing of the target, then this should have exaggerated the effects of storage unit size. What this analysis implies is that the interaction between storage unit size and context depends on the prime being redintegrative, but since the functions relating context to storage unit size (see Figure 3) were essentially parallel, what the results from Experiment 1 imply instead is that only the target was acting redintegratively.

The response time data for lures provided some indirect support for this possibility. If the primes redintegrate information that can spill over and interfere with the rejection of lures, and if the amount of interference from the prime increases as the storage unit size of the prime also increases, then the response time for correctly rejecting lures should have increased with the size of the storage unit for the primes. The results from the lure analysis clearly show that this did not happen. The rejection of lures did not change as a function of the storage unit size for primes, and, therefore, it seemed likely that the storage unit size of the primes was not responsible for the effect of storage unit size in the response time analysis of targets. By exclusion, this line of reasoning strongly implicates the target as the source of the storage unit size effect.

Although the absence of an interaction between storage unit size and context, as well as the response time results for lures, suggest that the source of the storage unit size effect in Experiment 1 was the target, the evidence is inconclusive for two reasons. First, the storage unit size of the prime and the target were confounded, and this made it impossible to attribute the effects of storage unit size to either the prime or the target. Second, the interpretation of the lure data requires caution because the process for rejecting lures may be very different from the process for identifying targets. For example, rejection of lures could occur simply by failing to detect an episodic relationship (Dosher, 1991; Dosher, McElree, Hood, & Rosedale, 1989), and therefore, might circumvent any processes that influence target identification.

4

Experiment 2

Experiment,

And it will lead you to the light.—Cole Porter

Experiment 1 established that there are storage unit size effects in an episodic priming task involving item recognition memory judgements. One shortcoming of that experiment, however, was that it did not provide insight into the source of that effect, and therefore leaves unresolved the issue of whether or not the prime was redintegrative. As a result, the purpose of Experiment 2 was to locate the source of the storage unit size effect: Specifically, are storage unit size effects the result of processing the prime, the target, or some combination of prime and target processing?

To address this question, Experiment 2 examined the specific hypothesis that redintegration of a storage unit from a prime can spill over and interfere with the processing of the target. Presumably, the larger the storage unit that the prime redintegrates, the greater should be the interference on target processing. This greater interference should reveal itself in the form of longer response times to targets preceded by primes from larger storage units. Some support for this follows from the research that interprets the effects of storage unit size on target response time as interference (e.g., Anderson, 1983). Additional support follows from other research that has demonstrated that participants with *low* memory spans have greater difficulty at suppressing irrelevant information from large storage units than do participants with *high* memory spans (e.g., Conway & Engle, 1994), and that researchers have found similar effects for older adults as compared to younger adults (e.g., Gerard et al., 1991).

To test this *interference* hypothesis, Experiment 2 included several design changes. First, the participants studied only word pairs and triplets. Second, the storage unit size for the primes and the targets was factorially combined in the different context condition[14]. This factorial arrangement produced three context conditions: same, different-2 (i.e., a different context prime with a storage unit size of 2), and different-3 (i.e., a different context prime with a storage unit size of 3); and two conditions of target storage unit size (2 and 3, respectively). Third and finally, the experiment employed three groups of participants. For one group of participants the prime-target SOA was 400 ms (short); for the second group of participants the SOA was 1000 ms (medium); and for the third group of participants the SOA was 2000 ms (long).

The rationale for the factorial arrangement of storage unit size for primes and targets in the different context condition was simply to isolate the primes and targets as separate sources for any effects of storage unit size. The rationale for the SOA manipulation was that previous research has shown that interference effects from irrelevant prime information (also referred to as inhibition effects) increase with an increase in SOA (e.g., Posner & Snyder, 1975). At short SOAs (400 ms or less) irrelevant information from a prime does not influence the processing of an upcoming target. At longer SOAs

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[14] Note that it is impossible to factorially arrange the storage unit size for the primes and the targets in the same context condition. This is because, by definition, the primes and targets in this condition must come from the same storage unit.

(greater than 400 ms), however, the interfering effects from an irrelevant prime get larger with increases in SOA.

In summary, Experiment 2 examined the independent effects of prime and target storage unit size on the time it takes to recognize targets as function of SOA. This was to test whether redintegration of a storage unit from a prime can spill over to interfere with the processing of the target.

HYPOTHESES

Although the main hypothesis for this experiment concerned the interference hypothesis, two additional hypotheses are introduced before this hypothesis to establish continuity with Experiment 1. Thus, for the same reasons outlined in Experiment 1 it was hypothesized that:

(1) participants would recognize targets faster when the prime came from the same storage unit as the target than when the prime came from a different storage unit, and that

(2) irrespective of context, the amount of time participants take to recognize a target would increase as the size of the storage unit for the target increased.

Finally, in view of the interference hypothesis, which means that the prime is redintegrative, and the relationship between interference effects and SOA, it was also hypothesized that:

(3) the response time to targets in the different-2 context condition should be faster than the response time to targets in the different-3 context conditions, but that this difference should increase with an increase in SOA (i.e., context should interact with SOA).

METHOD

Participants

The participants were 118 University of Manitoba undergraduates enrolled in an introductory psychology course. Participants received course credit for their participation and all spoke English as their first language. The assignment of participants to groups was random. Ten participants' data were not included because of poor recall. This left data from 108 participants for the analyses with 36 participants tested at each SOA.

Design and Materials

The design of Experiment 2 was essentially the same as that used in Experiment 1, except for the factorial arrangement of prime and target storage unit size in the different context condition, and the SOA variable. In all, there were six experimental conditions at each level of SOA in Experiment 2: three levels of context by two levels of target storage unit size. The three levels of context were same, different-2, and different-3. The two levels of target storage unit size were 2 and 3. The factors of group, position, trial set, and verbal set were the same as in Experiment 1. These factors allowed the targets to be counterbalanced across both of the six list positions and the six experimental conditions involving context and target storage unit size. This counterbalancing scheme was the same for each level of SOA. Thus, group and SOA were between participant factors and the remaining variables were within participant factors.

The materials of Experiment 1 were modified to accommodate the addition of the different-2 and different-3 context conditions. These modifications involved the addition of two new word groups to each trial set for a total of 10 word groups per trial set. These new word groups were constructed from the quadruplets in Experiment 1. The recognition test trials were arranged to factorially combine the different-2 and different-3 context conditions with the target storage unit sizes of 2 and 3. In all other respects the materials of Experiment 2 were the same as those used in Experiment 1.

Procedure

The procedure was the same as that used in Experiment 1. The first two sessions were used by the participants to learn the word groups. In these sessions, the word groups were divided into seven blocks of 10 word groups each and the participants studied and recalled the words in each block. In the study portion, the participants constructed interacting images of the objects to which the words in each group referred. They did this by first imagining each member in the word group in their mind's eye, and then combined the members into a coherent image by linking the members of the word group together in a meaningful way. After constructing the image, the participants then gave a rating of the cohesiveness of the constructed image. They did this on a seven-point scale where 1 on the scale indicated *low cohesiveness* and 7 indicated *high cohesiveness*.

In the recall portion of each study block, the participants wrote responses to cues that appeared in a booklet. The instruction was to write down the words that were studied with cue next to the cue in the booklet.

The study-recall procedure was repeated for each block of word groups. After the last block, another test of recall was given to the participants for all the words that they had just studied. In this final test, a new set of cues from the word groups was selected and placed in random order on a sheet of paper. The instruction to the participants was the same as for each of the study-recall cycles; that is, they were to write next to each cue the other words that were studied along with the cue.

In the third session the participants were given the recognition memory test. The procedure for this test was the same as in Experiment 1.

RESULTS

Preliminary Results

Cohesion ratings. Only the cohesion ratings for the priming session were analyzed. Again there were significant differences between the study units in cohesion ratings, $F_1(1, 90) = 91.47$, $MSE = 2.437$; $F_2(1, 30) = 90.81$, $MSE = 2.455$; $F''(1, 90) = 45.75$, $MSE = 4.892$. Pairs had higher ratings ($M = 5.66$) than did triplets ($M = 5.23$). As in Experiment 1, ratings were in the high range of the scale and indicated that the participants perceived the study units to be highly cohesive.

Cued recall. The recall data were for the same performance measures used in Experiment 1. The analyses for the proportion of complete units recalled and the mean number of items-per-unit recalled were separate, and the data transformation, the inverse arcsine transformation, to the proportion of complete units recalled was the same as well. Table 6 shows the statistics from the untransformed data in the same format used in Table 3.

In the analysis of the data for complete units recalled, the main effects of storage unit size, $F_1(1, 90) = 50.53$, $MSE = 0.028$; $F_2(1, 30) = 41.53$, $MSE = 0.040$; $minF'(1, 81) = 22.80$, session, $F_1(2, 180) = 106$, $MSE = 0.043$; $F_2(2, 60) = 256$, $MSE = 0.019$; $minF'(2, 238) = 74.96$, and context, $F_1(2, 180) = 7.86$, $MSE = 0.014$; $F_2(2, 60) = 3.82$, $MSE = 0.030$; $minF'(2, 123) = 2.57$, $p < .09$, were significant. Additionally, there was a significant Storage Unit Size x Session

Table 6

Complete Units Recalled and Items-per-Unit Recalled in Experiment 2

	Proportion of Complete Units Recalled		Mean Number of Items-per-unit Recalled	
	Storage unit Size		Storage unit Size	
Context	2	3	2	3
		Session 1		
Different-3	.92	.83	.92	1.73
Different-2	.89	.77	.89	1.63
Same	.91	.80	.91	1.69
		Session 2		
Different-3	.99	.97	.99	1.96
Different-2	.98	.95	.98	1.93
Same	.98	.94	.98	1.92
		Session 3		
Different-3	.99	.98	.99	1.98
Different-2	.98	.99	.98	1.96
Same	.99	.98	.99	1.97

interaction, $F_1(2, 180) = 40.10$, $MSE = 0.012$; $F_2(2, 60) = 32.89$, $MSE = 0.018$; $minF'(2, 162) = 18.07$. No other effects in the analysis were significant.

As displayed in the left most portion of Table 6, the storage unit size, session and Storage Unit Size x Session interaction effects followed the same pattern of results as found in Experiment 1. Participants recalled more complete units when the study units were of a storage unit size 2 than when the study units were of a storage unit size 3. Scheffé tests, α=.10, applied to the session effect revealed that the proportion of complete units recalled improved significantly with each additional experimental session. Further analysis with Scheffé tests, α=.10, showed this improvement was greater between the first and second session than between the second and third session. As in Experiment 1, the Storage unit Size x Session interaction qualified both of these main effects. Inspection of Table 6 indicates that the participants recalled more complete units of storage unit size 2 only at the end of the first experimental session.

Scheffé tests, α=.10, applied to the main effect of context indicated a 2% advantage in the proportion of complete units recalled for the different-3 context study units over the same and different-2 context study units. The Scheffé tests also indicated that recall did not differ between the same and different-2 context study units.

The analysis of the mean number of items-per-unit recalled also revealed significant main effects of storage unit size, $F_1(1, 90) = 4537$, $MSE = 0.087$; $F_2(1, 30) = 7646$, $MSE = 0.052$; $minF'(1, 111) = 2847$, session, $F_1(2, 180) = 80.96$, $MSE = 0.081$; $F_2(2, 60) = 238$, $MSE = 0.028$; $minF'(2, 240) = 60.38$, and context, $F_1(2, 180) = 7.28$, $MSE = 0.022$; $F_2(2, 60) = 4.04$, $MSE = 0.040$; $minF'(2, 132) = 2.60$, $p<.08$. The Storage Unit Size x Session interaction, $F_1(2, 180) = 54.83$, $MSE = 0.035$; $F_2(2, 60) = 64.19$, $MSE = 0.030$; $minF'(2, 194) = 29.57$, and the Context x Session interaction, $F_1(4, 360) = 5.50$, $MSE = 0.012$; $F_2(4, 120) = 2.59$, $MSE = 0.026$; $minF'(4, 242) = 1.76$, $p<.14$, were significant as well. No other effects were significant in the analysis that involved the storage unit size, session, and context factors.

As reported previously, the number of items-per-unit recalled increased as the number of items in a study unit increased. Participants recalled more items from a study unit when the study unit was of a storage unit size 3 than when it was of a storage unit size 2. Similarly, post hoc analysis of the session effect with Scheffé tests, α=.10, established that the number of items-per-unit recalled differed between session 1 and session 2, but not between session 2 and session 3. Finally, the storage unit size effect depended on the number of experimental sessions. As can be seen in the right most portion of Table 6, the smallest effect occurred at the end of the first experimental session and the largest effect occurred at the end of the second and third experimental sessions. The storage unit size effect, however, did not appear to change between the second experimental session and the third experimental session.

The main effect of context for items-per-unit recalled followed the same pattern of results as found for complete units recalled. Analysis of this effect with Scheffé tests, α=.10, indicated a small advantage for the different-3 context study units over the same and different-2 context study units, which did not differ from each other. Furthermore, the context effect depended on the experimental session. Inspection of Table 6 reveals that, at the end of the first experimental session, each of the context conditions differed from each other. The number of items-per-unit recalled was greatest for different-3 study units, moderate for same context study units, and poorest for different-2 study units. The context conditions did not appear to differ from each other after the second or the third experimental session.

Accuracy. Table 7 shows the proportion of "old" responses to test items on the recognition memory test in Experiment 2. Again this table clearly shows that participants were very good at discriminating between "old" and "new" targets on the recognition memory test. For each storage unit size, the proportion of "old" responses to targets requiring "old" responses was well above chance levels (M = .96), whereas this same proportion for lures was well below chance levels (M = .04).

Priming Results

Target priming. The data transformation and reporting procedures for the target priming data are the same as those used in the previous experiment.

Table 7

Proportion of "Old" Responses by Context and Target Storage Unit Size in Experiment 2

Context	Test Item	Correct Response	Target Storage unit Size 2	3
		Short SOA (400 ms)		
Different-2	Target	OLD	.94	.92
Different-3	Target	OLD	.96	.92
Same	Target	OLD	.99	.99
	Lure	NEW	.03	.04
		Medium SOA (1000 ms)		
Different-2	Target	OLD	.98	.98
Different-3	Target	OLD	.99	.96
Same	Target	OLD	.99	.99
	Lure	NEW	.05	.04
		Long SOA (2000 ms)		
Different-2	Target	OLD	.95	.89
Different-3	Target	OLD	.94	.87
Same	Target	OLD	.98	.95
	Lure	NEW	.04	.04

Note. The prime storage unit size is equal to the target storage unit size for the same context targets and the lures.

Table 8 shows the statistics for the priming data from each level of SOA. Within each SOA, the first two rows present mean response time, standard error, and error rate data for the different context condition, and the last two rows present these statistics for the same context condition. Within each context, the first row contains the statistics for targets that have primes from a storage unit size 2, and the second row contains the statistics for targets that have primes from a storage unit size 3. The left-most and right-most

Table 8

Means and Standard Errors in Milliseconds and Errors (e) for the Context and Storage unit Size Conditions in Experiment 2

	Target Storage Unit Size					
	2			3		
Context	M	SE	e	M	SE	e
	Short SOA (400 ms)					
Different						
2	738	15	.06	785	15	.08
3	734	17	.04	805	18	.08
Same						
2	587	15	.01			
3				612	15	.01
	Medium SOA (1000 ms)					
Different						
2	833	20	.02	836	19	.02
3	798	19	.01	854	20	.04
Same						
2	654	18	.01			
3				722	20	.01
	Long SOA (2000 ms)					
Different						
2	733	15	.05	801	20	.11
3	725	14	.06	797	16	.13
Same						
2	593	15	.02			
3				658	17	.05

portions of Table 8 use the same format as in Table 5. Figure 4 depicts the values contained in Table 8.

Again, the Context x Storage unit Size interaction was not significant in the analysis of the reaction time data (all Fs<1). Nor was there any indication of an SOA x Context interaction. There was a significant context effect for reaction times, $F_1(2, 180) = 179.94$, $MSE = 0.020$; $F_2(2, 60) = 170.97$, $MSE = 0.021$; $F''(2, 175) = 87.95$, $MSE = 0.41$; and a significant storage unit size effect, $F_1(1, 90) = 66.06$, $MSE = 0.015$; $F_2(1, 30) = 50.85$, $MSE = 0.019$; $F''(1, 78) = 29.06$, $MSE = 0.034$. Scheffé tests, $\alpha = .10$, on the context effect revealed that the responses to same context targets was 150 ms faster than the responses to either of the different context targets, but that the responses to the different-2 and the different-3 context targets did not differ.

The overall error rate for this experiment was small ($M = 0.06$). Similar to the response time data, there was a main effect of context, $F_1(2, 180) = 16.97$, $MSE = 0.012$; $F_2(2, 60) = 13.81$, $MSE = 0.014$; $minF'(1, 162) = 7.61$. Scheffé tests, $\alpha = .10$, indicated that responses to same context targets were 4% more accurate than to either of the different context targets, but that the responses to different-2 and different-3 context targets did not differ in accuracy. Also, there was a significant main effect of storage unit size, $F_1(1, 90) = 24.30$, $MSE = 0.010$; $F_2(1, 30) = 18.90$, $MSE = 0.012$; $minF'(1, 79) = 10.63$; and SOA, $F_1(2, 90) = 16.41$, $MSE = 0.015$; $F_2(2, 60) = 17.16$, $MSE = 0.014$; $minF'(2, 145) = 8.38$. The significant SOA x Storage Unit Size interaction for error rates qualified these effect , $F_1(2, 90) = 4.69$, $MSE = 0.010$; $F_2(2, 60) = 4.25$, $MSE = 0.010$; $minF'(2, 141) = 2.23$, $p < .12$. Inspection of Table 8 suggests that the SOA x Storage Unit Size interaction for the error rates was the result of a storage unit size effect that occurs at the long SOA. At the long SOA, participants were 5% more accurate in responding to targets from storage unit size 2 than to targets from a storage unit size 3. There was no effect of storage unit size in error rates at either of the two shorter SOAs.

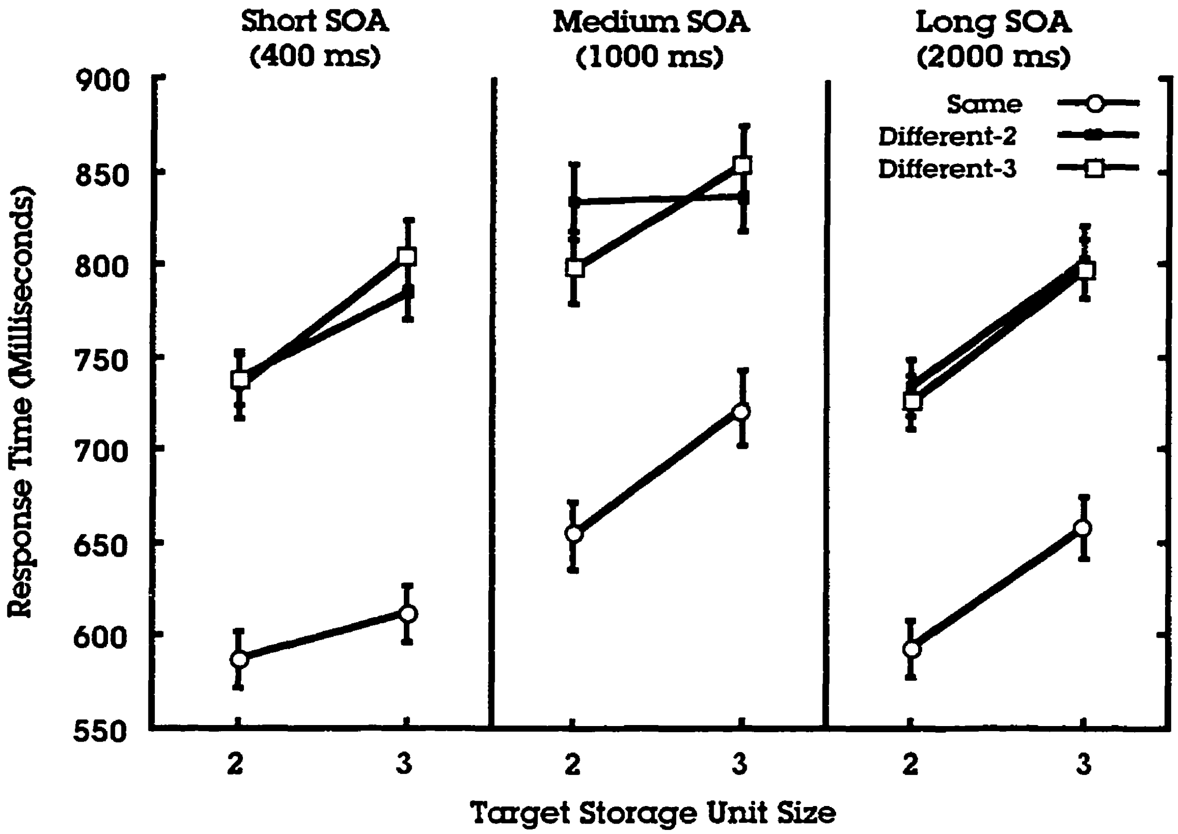

Figure 4. Response time to targets at each SOA and target storage unit size for the same, different-2,and different-3 context conditions. In the same context condition the prime and target came from the same storage unit, and, therefore, they had the same storage unit size. In the different-2 context condition, the prime came from a different storage unit than the target and its size was two. In the different-3 context condition, the prime also came from a different storage unit than the target but its size was three. Error bars indicate ±1 standard error of the mean.

Lure RTs. The analysis of the RT data for lures used a 3 (SOA) x 2 (Prime Storage unit Size) analysis of variance. SOA was a between participants factor while prime storage unit size was a within participants factor. As in Experiment 1, these data were transformed to common logarithms before analysis. There were no significant effects in the analysis of these data.

DISCUSSION

The main effect of context and the main effect of target storage unit size found in Experiment 2 clearly supported Hypothesis (1) and Hypothesis (2). Together these effects represent an important replication and extension of the effects found in Experiment 1. Insofar as context effects provided an index of integration, these results strongly uphold the integrative function of interactive imagery. Moreover, the storage unit size effect has firmly established that the participants responded to targets from small storage units faster than they do to targets from large storage units. This result further supports the idea that it takes longer to redintegrate large than small storage units from memory. What is more important, this result has demonstrated that target processing can be a source for the storage unit size effect, and therefore lends support to the conclusion that the target can be redintegrative.

The results from Experiment 2 were also clear in that they disconfirmed Hypothesis (3). There was no indication that the participants responded faster to targets following different-2 primes than they did to targets following different-3 primes at any SOA (see Figure 4). Moreover, in the one instance where there seemed to be some separation between these context conditions (see the medium SOA group in Figure 4), the different-2 context condition was, in fact, slower than the different-3 context condition. As a result, there was no support for the hypothesis that prime processing can spill over and interfere with the processing of the target, and therefore this result implied that the prime was not redintegrative in this experiment.

The broader implication of this conclusion, however, is that it explains why the predicted interaction between context and storage unit size was not supported in Experiment 1 (see Hypothesis 3 from Experiment 1). The explanation is just that the basic assumption upon which the prediction rested appears wrong. Consequently, had it been known that the primes were not redintegrative, then a very different prediction concerning the relationship between context and storage unit size might have been made at the outset.

5

General Discussion

The results from the two experiments demonstrated that the participants responded to same-context targets faster than they did to different-context targets. Both experiments also demonstrated that the participants responded faster to targets from small storage units than they did from large storage units. Although the results of Experiment 1 were inconclusive as to the source of the storage unit size effect, the results from Experiment 2 demonstrated that the target was the source of this effect.

The results lead to the conclusion that item recognition can involve the redintegration of a storage unit from memory, but that only the target, as opposed to the prime, initiated the redintegration stage of retrieval. In supporting this conclusion, the results from these experiments join with those of Johns (1985) in supporting the more general conclusion that a recognition test probe can start the retrieval of contextual information from memory.

The broader implication of this conclusion is that redintegration can contribute to recognition memory by establishing an episodic context that allows the distinctiveness of a test item to emerge at retrieval. Such a view of the contribution of redintegration to recognition is in keeping with the context-relative view of distinctiveness (e.g., Begg, 1982; Hunt & Smith, 1996; Jacoby & Craik, 1979; Jacoby et al., 1979). It is also in keeping with the more general notion that organizational processes are important for item retrieval (Hunt &

Smith, 1996), and that redintegration can be a critical part in establishing the initial interpretation (i.e., meaning) of an item at test (Masson & MacLeod, 1992).

Although the results supported the conclusion that the targets were redintegrative, the results from the experiments were equally clear in that they showed that the primes were not redintegrative. In this regard, both experiments failed to provide evidence for an interaction between context and storage unit size as would be expected if both the primes and the targets were redintegrative. Additionally, the results from Experiment 2 showed that there was no evidence for the interference hypothesis. The participants did not respond faster to targets preceded by different-2 primes than they did to targets preceded by different-3 primes, nor was there any indication that SOA interacted with response time to targets in the different context conditions.

Why were the Primes not Redintegrative?

The results raise a question about why the primes were not redintegrative. One possibility is that the participants may have ignored the primes and focused on making recognition judgements to the targets. As a consequence, the participants would not have made contact with the storage units in memory and redintegrated the contents of those storage units. This possibility, however, seems unreasonable in view of the robust context effects found in the experiments. The effects of context strongly support the contention that participants were reading the primes and making contact with their respective storage units in memory.

A more reasonable possibility is that reading the primes in the procedure for testing the targets may not have required the participants to redintegrate the storage units from memory. The organization-redintegration hypothesis suggests one reason for this possibility. The organization-redintegration hypothesis maintains that the value of the information contained in a storage unit depends on the purpose of its use (Begg, 1983). The implication is that information redintegrated from memory might not have been useful for reading the prime, and therefore made redintegration superfluous.

A further implication of this organization-redintegration analysis suggests that the task given to the participants for processing the prime may be important in determining whether a prime will be redintegrative. There is some indirect support for this proposal when it is considered that a major difference between the Halldorson et al. (1990) study and the present set of studies was in the way that the participants processed the prime. In the Halldorson et al. (1990) study the participants recognized both the primes and the targets. In the present set of studies, the participants simply read the primes and recognized the targets. The suggestion is that recognizing the primes versus reading the primes may account for the different outcomes in the Halldorson et al. (1990) study and the experiments reported here.

The suggestion that the task for processing the prime may determine whether the prime is redintegrative is consistent with other research that has shown that the nature of prime processing can dramatically alter the priming effect (Henik, Friedrich, & Kellog, 1983; Lewandowsky, 1986; Smith, 1979; Smith, Theodor, & Franklin; 1983). For example, some research has demonstrated that searching the prime for a letter can influence the priming effect (e.g., Henik et al., 1983; Smith, 1979; Smith et al., 1983). Given such results, it seems reasonable that the task for processing the prime can have an impact on whether redintegration occurs.

A goal for future research, therefore, should be to compare the impact of recognizing and reading primes in a priming procedure that examines storage unit size effects on target recognition. The expectation would be that results similar to Halldorson et al. (1990) should be obtained where the prime and target are recognized, but that the results of the current studies would be obtained with a prime that is read and a target that is recognized. Other studies along this line could be designed to explore the source of storage unit size effects as done in the present set of studies.

The Context Effect

Some might argue that the context effect invalidates the conclusion that the primes were not redintegrative. The rationale for this argument follows from an expectancy account of the context effect. The expectancy account maintains that the participants use the prime to anticipate the target (e.g., Cañas & Bajo, 1994; Stolz & Neely, 1995). The idea is that, when participants process the prime, the participants form an expectancy set that may contain the upcoming target. When the target is a member of the expectancy set then the response to the target is faster than when the target is not a member of the expectancy set. Since same-context primes form expectancy sets that are more likely to contain upcoming targets than different-context primes, response times to targets in the same context condition are faster than in the different context condition. If redintegration is the retrieval process that is responsible for the formation of the expectancy set, then it follows that the context effect suggests that the primes were redintegrative. This line of reasoning clearly contradicts the conclusion that the primes were not redintegrative.

Although the expectancy account of the context effect implies that the primes were redintegrative, there is an alternative account of the context effect that does not require that the primes be redintegrative. This alternative account is similar in spirit to the *location-shifting model* that Meyer and Schvaneveldt (1971) have proposed. The general idea behind this model is that storage units occupy specific locations in memory and that the distance between these locations varies. Now suppose that (a) it takes time to shift from one location to the next, and (b) that the time to shift between locations increases with the distance between locations. Suppose further that prime processing simply locates or contacts a storage unit in memory. Then a prime that contacts a storage unit that is in the proximity of the target would produce a faster response to the target than a prime that contacts a storage unit that is further away. Consequently, a same-context prime would put the participants closer to the storage unit that contains the target than a different-context prime, and this difference in proximity would account for the context effect. Thus, it is possible to account for the context effect *without* the primes being redintegrative.

Do the Results from this Research Present a Problem for Dual Coding Theory?

Dual coding theory proposes that the processing of verbal codes is sequential, whereas the processing of nonverbal codes is synchronous and allows for simultaneous access to information (i.e., Paivio, 1986, 1991). Some researchers have interpreted this to mean that access to mental images should not show the effects of storage unit size, and therefore claim that such effects invalidate dual coding theory (e.g., Heil, et al., 1994). In view of such an argument, some might consider the findings reported here as incompatible with dual coding theory.

There are at least two reasons why the data from this experiment do not necessarily support such a conclusion, however. One reason, similar to the argument made in the Literature Review, is that synchronous access to information should not necessarily mean instantaneous access, nor should it necessarily mean that storage unit size should have no effect on the amount of time it takes to access the information. Consequently, storage unit size effects may only indicate the amount of time it takes to access storage units of different size, and do not necessarily indicate anything about whether the access was simultaneous.

A second and more compelling reason, however, is based on a study by Bersted (1983) who has shown that storage unit size influenced response time in a memory scanning task when participants described interactive images as compared to when participants did not describe interactive images. From a dual coding perspective, this result could be interpreted to mean that described images were represented by verbal codes as well as by nonverbal codes. One consequence of the addition of these verbal codes to the described images might have been that verbal codes imposed sequential constraints on the processing of the interactive images. The presence of these verbal codes for the described images would then be expected to produce the linear increase in response time observed by Bersted (1983) in the memory scanning task.

One implication of the dual coding analysis of the Bersted (1983) results is that it also applies to the set of results reported here. Specifically, it is possible that the participants might have adopted a strategy whereby they added verbal descriptions to their images. For example, an image that contained BOY, LARK, STRING, WINDOW may have been accompanied by a description such as, *The boy played with the string while the lark perched on the* *window*. Indeed, such an elaborate verbal description would be expected to place sequential constraints on the processing of any information that was synchronously available through imagery, and therefore could also be responsible for any storage unit size effects.

One conclusion from this analysis is that unless the possibility of sequential constraints from verbal codes can be ruled out, then storage unit size effects are inconclusive as to whether the dual coding assumption of synchronous processing of images has been violated. Since the research herein does not rule out the possibility of verbal codes, the use of these findings to support criticisms of dual coding theory is unjustified. In fact, future research may even show more conclusively that the findings in these experiments are well within the purview of dual coding theory.

In this regard, it might be interesting to compare an imagery group with an imagery-plus-description group, using the current item recognition memory task, rather than the memory scanning task. Another possibility might be to examine the effects of separate imagery instructions or to use abstract nouns. Presumably both of these conditions represent situations of *low* integration, and, therefore, should rely less extensively on synchronous processing of images.

How are the Effects of Storage Unit Size in these Experiments to be Interpreted?

In addition to the dual coding analysis of the storage size effects in these experiments, a review of the literature revealed that there are at least three other interpretations for these effects. These alternative interpretations are scanning, spreading activation, and synergistic ecphory[15].

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[15] Ecphory means to be made known.

Scanning. The scanning interpretation of storage unit size effects is straightforward. Once a storage unit is available in primary memory, recognition of the target follows a comparison process that involves a serial exhaustive scan of the storage unit (e.g., Wickens et al., 1985). The larger the storage unit that needs scanning, the more time it takes to recognize the target. The strength of the scanning interpretation is its elegance. At the same time though, the scanning interpretation does have a drawback. The scanning interpretation does not easily account for studies that have shown that interactive imagery does not produce a storage unit size effect in a memory scanning task (e.g., Bersted, 1983; Seamon, 1972).

Spreading activation. A spreading activation perspective suggests that the effects of storage unit size are just the result of resource limited activation being divided among a set of links that connect the elements in a storage unit (see Anderson, 1983; Cantor & Engle, 1993). As the number of elements in a storage unit increases so too does the number of links in the storage unit. As a consequence of fewer links, targets in small storage units receive more activation than do targets in large storage units, and since response time is related to amount of activation, targets from small storage units are responded to faster than are targets from large storage units.

One strength of the spreading activation interpretation is that there are several well-developed models of spreading activation that can account for the effects of storage units size (e.g., Jones & Anderson, 1987; Reder & Anderson, 1980). Another strength of the spreading activation interpretation is that it can account for priming effects in a wide variety of tasks (e.g., McNamara 1992; but see Dosher & Rosedale, 1989 and Ratcliff & McKoon, 1988 for a different view). Therefore, one of the attractions of the spreading activation interpretation is that it might provide an account for both the storage unit size effect and the context effect. Despite these strengths, one drawback of the spreading activation interpretation is that it does not readily account for studies that have shown that highly integrated materials attenuate effects of storage unit size (e.g., Myers, O'Brien, Balota, & Toyofuku, 1984; Radvansky, Spieler, & Zacks, 1993; Radvansky & Zacks, 1991).

Synergistic ecphory. The synergistic ecphory model (Tulving, 1982, 1983) provides another interpretation. This model suggests that the storage unit size effect is the result of qualitative differences in the ecphoric information that is available to support a response. The idea is that the quality of this ecphoric information is higher for a test of a probe from a small storage unit, than for a test of a probe from a large storage unit, and that this difference translates into faster response times for test probes from smaller storage units. According to the model, this translates into faster response times because the ecphoric information that is of higher quality exceeds a conversion threshold for performance by a greater amount than does ecphoric information of lesser quality.

To see that quality of ecphoric information can differ between test probes from small and large storage units, consider that ecphoric information is the product of two sources of information, these being the retrieval information found in the test probe and the trace information found in memory (Tulving, 1982, 1983). Now consider that the quality of ecphoric information is a direct function of the proportional overlap between these sources. Consider further that this overlap is greater for small storage units than large storage units. The greater overlap in information for small storage units is easy to illustrate. A test probe from a storage unit that contains two members potentially represents 50% of the trace information contained in the storage unit, whereas a test probe from a storage unit that contains three members only represents about 33% of the trace information in the storage unit. Consequently, the quality of ecphoric information that supports a response to a test probe is of higher quality for small storage units than for large storage units.

Limitation

The discussion of alternative interpretations for the storage unit size effect points to the main limitation of the research. Namely, the research does not discriminate between the various interpretations of storage unit size effects, whether the interpretation be scanning, spreading activation, synergistic ecphory, or redintegration. A goal for further research might be to explore these alternative interpretations in more detail and to design experiments that can distinguish the various views in their account of storage unit size effects.

Despite these alternative interpretations, the redintegration interpretation is preferable because (1) it fits within the theoretical frameworks that have been used to explain the organizational effects of imagery instructions, (2) it can explain results where a priming stimulus operates redintegratively and attenuates the effects of storage unit size (e.g., Halldorson et al., 1990), (3) it complements other mechanisms as a major retrieval component in item recognition, and (4) it is parsimonious.

Conclusion

The results from the current research support the conclusion that the recognition of an item can involve the redintegration of a storage unit from memory. The redintegration of the storage unit, however, starts with the processing of the target and seems to be independent of the processing of the prime. The wider implication of these conclusions is that redintegration can play an important part in providing the initial learning context that is so critical for good item recognition memory. As a result, redintegration deserves special consideration in accounting for the recognition of items that belong to integrated storage units, and should not be forgotten when considering the broader problem of retrieval in recognition memory.

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Appendix A

EXPERIMENT 1A AND EXPERIMENT 1B

EXPERIMENT 1A AND EXPERIMENT 1B

Experiment 1A and Experiment 1B were essentially the same as Experiment 1 and represent progressive developments in the method for Experiment 1. Experiment 1A, the first in the series, included only a priming session and thus gave participants only one opportunity to learn the test material. A consequence of this one-shot approach to the training of the test material was that memory for the material was very different between some of the experimental conditions (see the proportion of complete units recalled for Experiment 1A in Table A1). This difference between experimental conditions left open the possibility that the set size effect for the target priming data (see the description of the results for Experiment 1A and Table A2) might simply be the result of differences in learning the material rather than differences in set size. To overcome this difficulty, a pair of training sessions preceded the priming session in Experiment 1B. The purpose of these additional training sessions was to provide the participants with more opportunity to learn the test material and to equate the conditions in memory for this material more closely.

Although the addition of the training sessions in Experiment 1B produced the desired result (see the bottom row of Table A1), Experiment 1B, as well as Experiment 1A, suffered from an additional problem; the design of the test lists used during the priming session were such that the probability of a lure following a prime increased as set size of a storage unit increased. The problem that this relationship presents is that recognition performance decreases with increases in the number of lures (cf., Paivio & Bleasdale, 1974), and this suggests that the participants might have found the recognition task more difficult for targets from the large than the small sets. Despite the lack of any compelling evidence to suggest that this was indeed a problem for the participants (see the results for the error data in Table A2), Experiment 1 used test lists that equated the probability of a lure following a prime in all conditions. Equating the test lists this way for Experiment 1 was desirable because it removed differences in the likelihood of a lure as an explanation of set size effects in the priming data.

Experiment 1A

Method

Participants. The participants were 43 University of Manitoba undergraduates enrolled in an introductory psychology course. Participants received course credit for their participation and all spoke English as their first language. The assignment of participants to groups was random. Six participants recalled less than 50% of the targets on the cued recall test. The data were dropped for these six participants as a result. Additionally, data from one participant was lost because of a disk error. This left data from 36 participants for the analyses.

Materials, design, and procedure. The materials, design, and procedure were essentially the same as those described for Experiment 1. Compared to Experiment 1, Experiment 1A included only a priming session and this session ran as described for Experiment 1. Besides there being only a single session in Experiment 1A, the test lists used for the priming session also differed somewhat from those used in Experiment 1. In particular, the probability of a lure following a prime on a test trial increased as the size of the storage unit increased. In all other respects the test lists used in Experiment 1A were the same as those used in Experiment 1.

Results

Cued recall. Analyses of the participants' recall data were for the proportion of complete units recalled and the mean number of items-per-unit recalled. The analysis of the complete unit recall data was separate from the analysis of the items-per-unit recall data. An inverse arcsine transformation of the unit recall data preceded the analysis. The items-per-unit recall data were untransformed. Where appropriate for these data, the reported Fs and associated MSEs are for the transformed data. All of the statistics shown in Table A1, however, are for the untransformed data.

Table A1

Complete Units Recalled and Items-per-Unit Recalled in Experiments 1A and 1B

Session	Proportion of Complete Units Recalled			Mean Number of Items-per-unit Recalled		
	Set Size			Set Size		
	2	3	4	2	3	4
			Experiment 1A			
1	.84	.67	.61	.84	1.44	2.12
			Experiment 1B			
1	.91	.80	.65	.91	1.67	2.19
2	.98	.93	.91	.98	1.89	2.80
3	1.00	.97	.94	1.00	1.94	2.89

Table A1 shows the untransformed mean proportion of complete units recalled and the mean number of items-per-unit recalled for Experiments 1A and 1B. The left-hand side of the table contains the data for complete units recalled, and the right-hand side of the table contains the data for items-per-unit recalled. For each type of recall data, the first, second, and third columns show the statistics for targets from a set size 2, a set size 3, and a set size 4, respectively. The rows of the table show the statistics for each experimental session within an experiment. As the table indicates, Experiment 1A had only one session (i.e., one priming session), whereas Experiment 1B had three sessions (i.e., two training sessions followed by one priming session).

The analysis of the recall data revealed a significant set size effect for both complete units recalled, $F_1(2, 60) = 6.04$, $MSE = 0.041$; $F_2(2, 60) = 22.90$, $MSE = 0.029$; $minF'(2, 90) = 4.78$, and items-per-unit recalled, $F_1(2, 60) = 13.10$, $MSE = 0.030$; $F_2(2, 60) = 337$, $MSE = 0.085$; $minF'(2, 65) = 12.61$. No other effects were significant in the analysis.

Scheffé tests, $\alpha = .10$, of the set size effect for the proportion of complete units recalled showed that participants recalled a greater proportion of the set size 2 units than either of the set size 3 or set size 4 units, but that recall of the set size 3 and set size 4 units did not differ from one another. On average, the participants were able to recall 20% more units of a set size 2 than either of a set size 3 or a set size 4.

A similar set of follow-up analyses examined the set size effect for the items-per-unit recalled. The Scheffé tests in these analyses established that the participants recalled more items per unit as the set size of the study unit increased. Participants recalled 71% more items from study units of a set size 3 than a set size 2, and recalled 47% more items from a set size 4 than from a set size 3.

Target priming. Each participant made responses to 36 "old" target items. For each response, a computer recorded the response time (RT) and the response accuracy. The analysis of the RT data was separate from the analysis of the accuracy data. For the RT data, the targets on which the participants made errors were estimated from the mean response time for the condition in which the error occurred. The resulting data were then transformed using common logarithms and the analysis was done on these transformed data.

For the accuracy data, the analysis was for the proportion of errors made by each participant in each of the experimental conditions. An inverse sine transformation was carried out on these target error rates before analysis.

All reported Fs and associated MSEs are for the transformed data. The priming statistics shown in Table A2 and Figure A1, however, are for the transformed data in the units of the original measurement scale. For these data the units of the original scale are in milliseconds (ms). For the accuracy data, however, the data are for the untransformed proportions.

Table A2 shows the mean response times, standard errors, and error rates for Experiments 1A and 1B. For each experiment, the first and second rows present the mean response time, standard error, and error rate for the different and same context conditions, respectively. The left-most portion of Table A2 contains the mean response time, standard error, and error rate for set size 2; the middle portion of Table A2 contains these statistics for

Table A2

Means and Standard Errors in Milliseconds and Errors (e) for the Context and Set Size Conditions in Experiments 1A and 1B

	Set Size								
	2			3			4		
Context	M	SE	e	M	SE	e	M	SE	e
				Experiment 1A					
Different	882	27	.06	930	27	.07	915	30	.11
Same	759	28	.05	823	27	.04	817	26	.07
				Experiment 1B					
Different	726	17	.07	794	21	.11	806	20	.07
Same	592	19	.02	642	20	.02	654	19	.03

set size 3; finally, the right-most portion of Table A2 contains the mean response time, standard error, and error rate for set size 4.

The statistics for the priming data from Experiment 1A are in the top portion of Table A2 and are shown graphically in Figure A1. In the analysis of the target response time data the Context x Set Size interaction was not significant, (all Fs<1). The analysis of the target response time data did, however, reveal two main effects. The first was a main effect of context, $F_1(1, 30) = 29.27$, MSE = 0.034; $F_2(1, 30) = 41.72$, MSE =0.024; $F''(1, 58) = 17.85$, MSE = 0.058. The participants were 109 ms faster in responding to same context targets than to different context targets. The second effect was a main effect of set size, $F_1(2, 60) = 3.06$, MSE = 0.034; $F_2(2, 60) = 3.28$, MSE = 0.032; $F''(3, 120) = 2.01$, MSE = 0.066, $p<.12$. A Scheffé test, $\alpha = .10$, revealed a significant contrast between the effect of set size 2 and the average effect of set size 3 and set size 4. Participants' responses to targets from set size 2 were 51 ms faster than the average of the two larger set sizes. Finally, the overall error rate was 0.06, and there were no significant effects in the analysis of the error rate data.

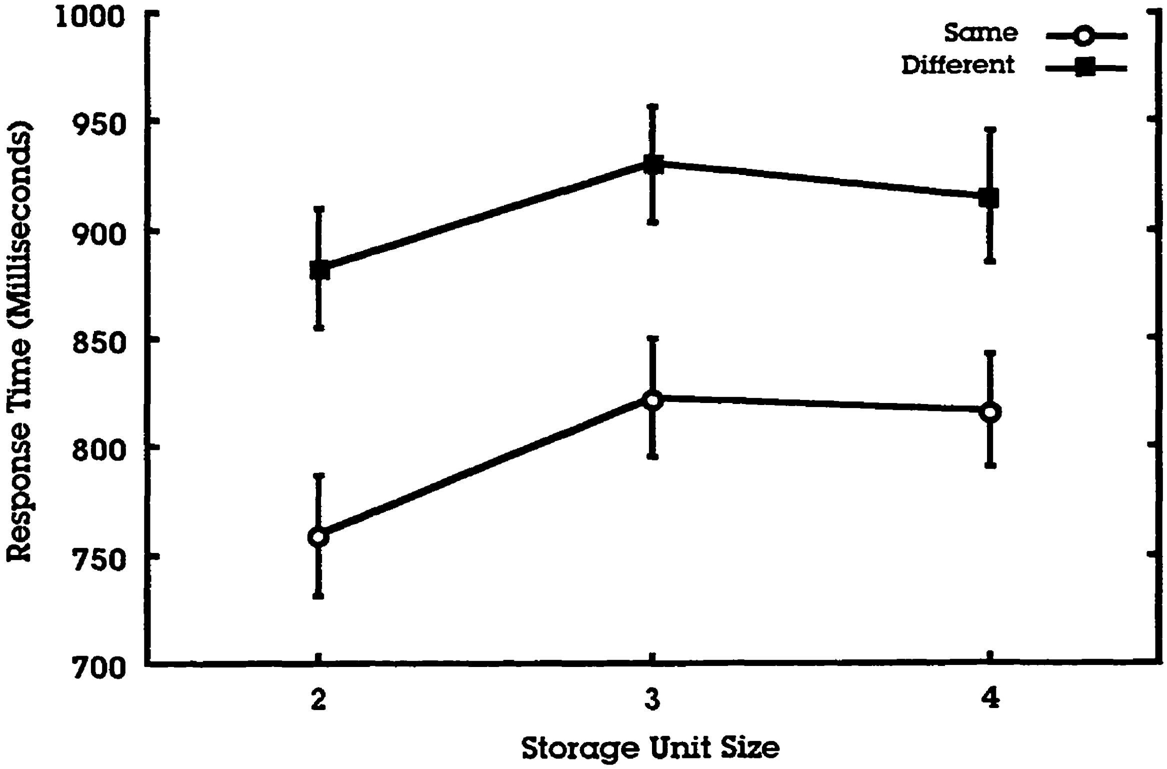


Figure A1. Response time to targets at each storage unit size for the same and different context conditions. In the same context condition the prime and the target came from the same storage unit. In the different context condition the prime and the target came from different storage units. Error bars indicate ±1 standard error of the mean.

Experiment 1B

Method

Participants. There were 36 participants from the same source as in Experiment 1A.

Materials, design, and procedure. The materials and design were the same as in Experiment 1A. The procedure in Experiment 1B differed, however. It included three sessions. The first two of these sessions were training sessions and the final session was a priming session. The additional training sessions provided the participants with some additional practice at integrating and retrieving the test material. The procedure for these sessions is described in the text for Experiment 1.

Results

Cued recall. The portion of Table A1 shows the recall data for the proportion of complete units recalled and the mean number of items-per-unit recalled. The analysis of the data for complete units recalled indicated a significant set size effect, $F_1(2, 60) = 16.67$, $MSE = 0.027$; $F_2(2, 60) = 40.48$, $MSE = 0.018$; $minF'(2, 102) = 11.81$, and a significant session effect, $F_1(2, 60) = 40.84$, $MSE = 0.047$; $F_2(2, 60) = 151$, $MSE = 0.014$; $minF'(2, 90) = 32.15$. A significant Set Size x Session interaction qualified both these main effects, $F_1(4, 120) = 8.87$, $MSE = 0.015$; $F_2(4, 120) = 24.17$, $MSE = 0.012$; $minF'(2, 198) = 6.49$, however. No other effects in the analysis were significant.

Scheffé tests, $\alpha = .10$, applied to the effect of storage unit size showed that each of the three levels of storage unit size differed in the proportion of complete units recalled. Apparently, the smaller the study unit, the greater was the proportion of complete units that participants recalled. Scheffé tests, $\alpha = .10$, applied to the session effect revealed that the proportion of complete units recalled improved significantly with each additional experimental session. Further analysis with Scheffé tests, $\alpha = .10$, showed this improvement was greater between the first and second session than between the second and third session. Finally, inspection of Table A1 suggests the source of the Set Size x Session interaction. The improvement in unit recall between the first and second experimental sessions grew larger as the size of the study set increased.

The analysis of the mean number of items-per-unit recalled revealed that the main effects of set size, $F_1(2, 60) = 836$, MSE = 0.193; $F_2(2, 60) = 2401$, MSE =0.068; $minF'(2, 97) = 620$, and session, $F_1(2, 60) = 36.47$, MSE = 0.182; $F_2(2, 60) = 118$, MSE =0.049; $minF'(2, 94) = 27.86$, were significant. As well, the Set Size x Session interaction was significant, $F_1(4, 120) = 28.62$, MSE = 0.061; $F_2(4, 120) = 32.55$, MSE =0.049; $minF'(4, 239) = 15.23$. No other effects in the analysis were significant.

Post hoc analysis of the storage unit size effect with Scheffé tests, α=.10, established that the number of items-per-unit recalled increased as the number of items in a storage unit increased. Post hoc analysis of the session effect with Scheffé tests, α=.10, established that the number of items-per-unit recalled differed between session 1 and session 2, but not between session 2 and session 3. Finally, the Set Size x Session interaction indicated that the session effect was greater for study units of set size 4 and set size 3 than it was for study units of set size 2.

Target priming. The statistics for the priming data from Experiment 1B are in the bottom portion of Table A2 and are shown graphically in Figure A2. As in Experiment 1A, the Context x Set Size interaction was not significant in the analysis of the response time data (all Fs<1), but the analysis did reveal two main effects. First, the context effect was significant, $F_1(1, 30) = 105.02$, MSE = 0.025; $F_2(1, 30) = 96.15$, MSE =0.028; $F''(1, 60) = 50.35$, MSE = 0.053. Responding to same context targets was 146 ms faster than responding to different context targets. Second, the main effect of set size was also significant, $F_1(2, 60) = 14.45$, MSE = 0.017; $F_2(2, 60) = 13.31$, MSE = 0.018; $F''(2, 120) = 7.47$, MSE = 0.035. Post hoc analyses of this effect with a Scheffé test, α = .10, indicated that the mean response time for targets from a set size 2 were significantly faster than that from either of the two larger set sizes, which did not differ significantly from each other. Responses to targets from set size 2 were faster by at least 59 ms than to targets from either set size 3 or set size 4.

The overall error rate in this experiment was 0.05. The analysis of the error rate data indicated that responding was more accurate for same context targets than for different context targets, $F_1(1, 30) = 11.85$, $MSE = 0.023$; $F_2(1, 30) = 22.83$, $MSE = 0.016$; $minF'(1, 55) = 7.80$. No other effects in the analysis of the error rate data were significant.

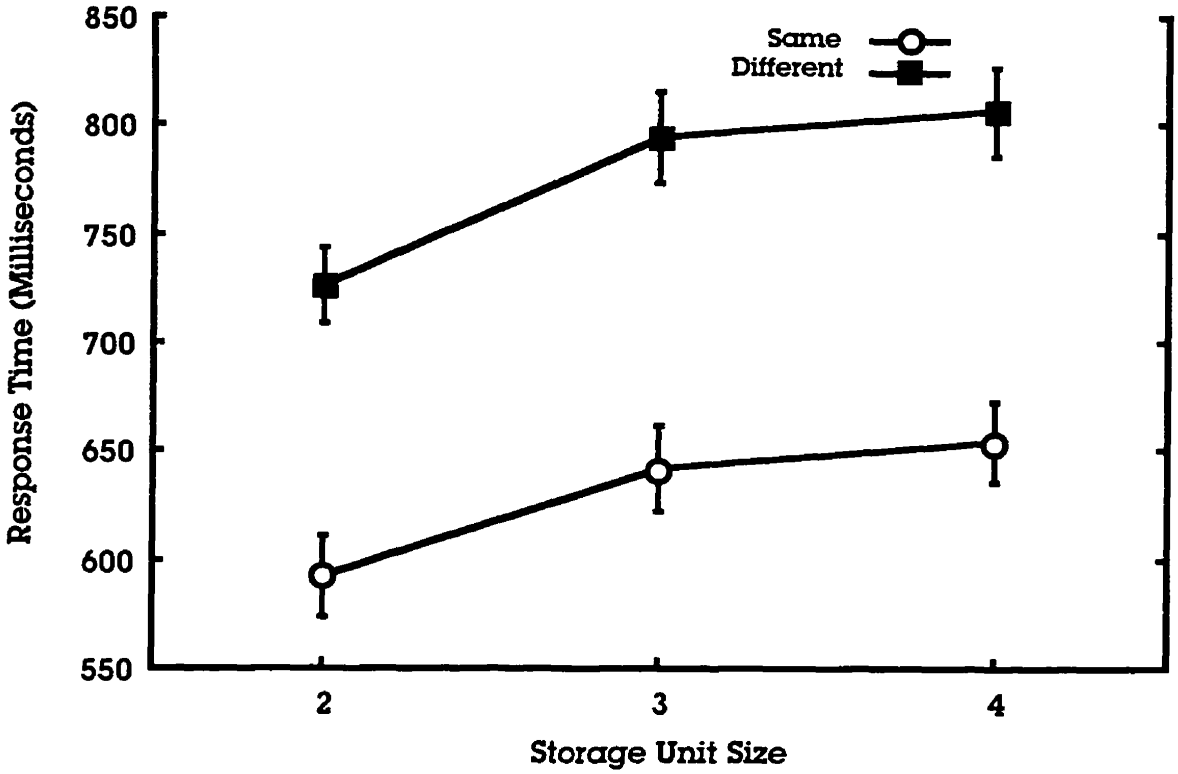


Figure A2. Response time to targets at each storage unit size for the same and different context conditions. In the same context condition the prime and the target came from the same storage unit. In the different context condition the prime and the target came from different storage units. Error bars indicate ±1 standard error of the mean.

Appendix B

B1. MATERIALS FOR EXPERIMENT 1 AND EXPERIMENT 2

B2. SET OF STUDY LISTS USED IN EXPERIMENT 1[16]

[16] Note that there were six such sets constructed for use in Experiment 1.

MATERIALS FOR EXPERIMENT 1 AND EXPERIMENT 2

	Triples					
Verbal Set	Different Context Prime	Same Context Prime	Target	Lure	Filler	Filler
			Trial Set 1			
1	ENGINE	STUDENT	GEM	LOBSTER	ICEBOX	CIRCLE
2	DRESS	HOUSE	SUNBURN	MAIDEN	SULPHUR	SHIP
3	MANTLE	DIRT	CHAIR	REVOLVER	HURDLE	ARROW
4	CHURCH	MARKET	BOWL	SLAVE	CELL	
5	JURY	FROG	STAR	MOUNTAIN	MICROSCOPE	
6	THORN	BEAVER	MORGUE	BLOOD	ABDOMEN	
			Trial Set 2			
1	FORK	CORD	WATER	SHEEPSKIN	PENCIL	WHEAT
2	TRUMPET	CIGAR	LAD	COTTAGE	ADMIRAL	IRON
3	BOARD	GARDEN	ANKLE	GOLF	BLISTER	GOBLET
4	PARTY	WOMAN	SCORPION	FLAG	DOCTOR	
5	SKILLET	WIGWAM	TRUCK	CAT	HARP	
6	BOTTLE	TOWER	KISS	VILLAGE	NIGHTFALL	
			Trial Set 3			
1	HALL	KING	BARREL	SCARLET	TOAST	PROFESSOR
2	STREET	FLOWER	SKIN	SNAKE	LAWN	ARMY
3	INK	WHALE	MACHINE	ORCHESTRA	TOY	TWEEZERS
4	SKULL	VOLCANO	AMBULANCE	CORN	COTTON	
5	NAIL	POLE	HOTEL	GRASS	VEST	
6	ACROBAT	LOCKER	TABLESPOON	MEAT	CATERPILLAR	
			Trial Set 4			
1	PAPER	CORNER	SKY	SLUSH	ELBOW	RAILROAD
2	MAST	HOUND	CELLAR	MISSILE	DOORMAN	HORSE
3	POTATO	DIAMOND	UMBRELLA	PEPPER	TOMAHAWK	LARK
4	NUN	NURSERY	CASH	PIPE	FLESH	
5	BEGGAR	SWAMP	WINDOW	BABY	GLACIER	
6	GREEN	BOY	STRING	SHORE	CANDY	
			Trial Set 5			
1	SPINACH	MOSQUITO	BAGPIPE	CORPSE	TICKET	LEMONADE
2	CLOTHING	WINE	DOVE	CLAW	CHIN	OCEAN
3	LETTER	OFFICER	CLOCK	JAIL	PHOTOGRAPH	HONEYCOMB
4	BUTCHER	MOSS	STORM	COFFEE	ARM	
5	STONE	FIRE	MONK	CHIEF	STEAMER	
6	MULE	HAMMER	COLLEGE	GIRL	BULLET	
			Trial Set 6			
1	FLASK	DAYBREAK	MAGAZINE	ELEPHANT	POSTER	LIBRARY
2	CANE	STRAWBERRY	CAMP	HOOF	TANK	GENTLEMAN
3	RATTLE	SALAD	HILLSIDE	GRANDMOTHER	DAFFODIL	PIANIST
4	CATTLE	COIN	FRIEND	HOSPITAL	FOAM	
5	CITY	TREE	BRONZE	LIP	HEADLIGHT	
6	WINTER	SHOES	FOX	BUTTER	SQUARE	

SET OF STUDY LISTS USED IN EXPERIMENT 1

Unit Size				
		Trial Set 1		
Pairs	MARKET	BOWL		
	FROG	STAR		
	JURY	ICEBOX		
Triplets	GEM	CELL	STUDENT	
	BEAVER	MORGUE	ARROW	
	THORN	MICROSCOPE	ABDOMEN	
Quadruplets	HURDLE	HOUSE	SUNBURN	SHIP
	SULPHUR	CIRCLE	DIRT	CHAIR
	ENGINE	CHURCH	MANTLE	DRESS
		Trial Set 2		
Pairs	SCORPION	WOMAN		
	TRUCK	WIGWAM		
	PENCIL	SKILLET		
Triplets	DOCTOR	CORD	WATER	
	GOBLET	TOWER	KISS	
	NIGHTFALL	BOTTLE	HARP	
Quadruplets	WHEAT	LAD	CIGAR	ADMIRAL
	IRON	BLISTER	ANKLE	GARDEN
	FORK	TRUMPET	PARTY	BOARD
		Trial Set 3		
Pairs	AMBULANCE	VOLCANO		
	HOTEL	POLE		
	TOAST	NAIL		
Triplets	COTTON	BARREL	KING	
	TABLESPOON	TWEEZERS	LOCKER	
	VEST	CATERPILLAR	ACROBAT	
Quadruplets	FLOWER	SKIN	ARMY	PROFESSOR
	MACHINE	WHALE	TOY	LAWN
	SKULL	INK	HALL	STREET
		Trial Set 4		
Pairs	NURSERY	CASH		
	SWAMP	WINDOW		
	BEGGAR	TOMAHAWK		
Triplets	SKY	CORNER	FLESH	
	LARK	BOY	STRING	
	CANDY	GLACIER	GREEN	
Quadruplets	HOUND	RAILROAD	DOORMAN	CELLAR
	ELBOW	DIAMOND	HORSE	UMBRELLA
	PAPER	POTATO	MAST	NUN

SET OF STUDY LISTS USED IN EXPERIMENT 1—*continued*

Unit Size				
		Trial Set 5		
Pairs	MOSS	STORM		
	MONK	FIRE		
	TICKET	STONE		
Triplets	MOSQUITO	BAGPIPE	HONEYCOMB	
	COLLEGE	HAMMER	ARM	
	STEAMER	MULE	BULLET	
Quadruplets	DOVE	CHIN	PHOTOGRAPH	WINE
	OFFICER	OCEAN	CLOCK	LEMONADE
	LETTER	SPINACH	BUTCHER	CLOTHING
		Trial Set 6		
Pairs	FRIEND	COIN		
	TREE	BRONZE		
	CITY	POSTER		
Triplets	DAYBREAK	PIANIST	MAGAZINE	
	SHOES	FOAM	FOX	
	WINTER	HEADLIGHT	SQUARE	
Quadruplets	CAMP	LIBRARY	STRAWBERRY	TANK
	GENTLEMAN	HILLSIDE	DAFFODIL	SALAD
	FLASK	CATTLE	CANE	RATTLE

Appendix C

INSTRUCTIONS

C1. INSTRUCTIONS FOR TRAINING SESSIONS

This experiment requires that you learn and remember groups of words. First you will study and rate a short list of word groups; then I will test your memory for the words in the list. You will repeat this study-test procedure for several lists.

How To Study the Word Groups

Each word group will appear on the computer screen and can have 2, 3, or 4 words in it. For each group of words, please construct an interacting visual image out of the words in each group. Form this image by first imagining the object to which each word in the group refers and then making them interact together in some way. Suppose, for example, that the words NUTMEG, LEMON, and FACTORY appear on the computer screen. You can combine these words into an interacting image by imagining lemons rolling out a factory door as nutmeg is being sprinkled over them. Please note that the image that you construct from the words in each group **does not have to be realistic**. You are free to construct your images any way you like as long as you form interactive images. So, let your imagination run wild!

How to Rate the Word Groups

After constructing an image for each group of words, the computer will prompt you to rate the cohesiveness of the image. Essentially, this rating involves your judgment of how well the objects in your image are "knit" together. When the objects in the image knit together very well, then you should assign the word group a "high" cohesiveness rating. If, on the other hand, the objects do not knit together very well, then you should assign a "low" cohesiveness rating to the word group.

Please indicate your cohesiveness rating when the computer displays the seven-point cohesiveness scale on the computer screen. Use the number 7 to indicate a high cohesiveness rating and the number 1 to indicate a low cohesiveness rating. Indicate your rating by pressing the number on the keyboard that corresponds to your rating.

Once you have entered your cohesiveness rating into the computer, the computer will automatically display the next word group for study. Repeat the study and rating procedure for this next group of words. Please note that you will study and rate each group of words twice before you write the memory test.

The Memory Test

When you have studied and rated the last word group in a list, I will test your memory for the words in the list. For this test try to remember the words in the same groupings you studied them. To help you with this, I will provide cue word that comes from a group of words you studied together. You job will then be to provide the remaining words that belong to the word group. For example, consider NUTMEG, LEMON, and FACTORY as a word group you studied in the list. If I provide NUTMEG as a cue word during the test, then you would provide LEMON and FACTORY as the missing words from the word group.

The cue words that I provide for the test appear in a test booklet. You should find this booklet next to the computer on the right hand side of the keyboard. If you can't find your booklet, ask me for one now!

Each booklet has a cover page and seven pages of cue words labeled ***Block 1*** through ***Block 7***. Before you go on with the instructions, please put your name, student number and telephone number on the front cover of the booklet, then turn to the page labeled ***Block 1***.

To use the booklet, simply write the word or words that you remember studying with the cue word in the blank spaces next to each cue. Please make sure that all the words you write down next to the cue come from the same group of words that you studied together.
The computer will display a message telling you when to write your answers in the booklet and what page to use. For example, after you study the first list of words, the message "RECALL Block 1" will appear on the screen. This means that you should write the words you remember from the first list on the page marked Block 1. Please note that the booklet has seven pages of cue words, one page for each list of word groups you study. Make sure that you write your answers for each list on the appropriate page.

After you have written down all the words you can remember, then you can begin to study the next list of words. To start the computer display for the next list of words press the <F10> key. Once you have done this, get ready to study and rate the next list of words. Repeat the study-test procedure for this new list of words.

Finally, feel free to reread these instructions. Once you have read the instructions, please raise your hand briefly to tell me that you are ready to begin. Please wait for my signal before you start the experiment. While you are waiting, rehearse the steps in the study-test procedure and prepare to ask me any questions you have about the procedure. I will give you a chance to ask these questions before we begin.

C2. Instructions for the Priming Session

This last part of the experiment is very similar to the other parts of the experiment. First you will study and rate a short list of word groups; then I will test your memory for the words in the list. This time, however, I will test your memory with a recognition memory test. As before, you will repeat this study-test procedure for several lists.

How to Study and Rate the Word Groups

Study and rate the word groups the same way you did in the other parts of the experiment. Form an interacting image from the words in each group and then rate the cohesiveness of the image.

The Recognition Memory Test

When you complete your rating for the last word group in a list, the computer will give you a recognition memory test. In this test the computer displays a cue word followed by a test word. Your task is to read the cue word and then make a recognition judgment about the test word. This judgment involves telling me whether you think the test word is an "Old" word or a "New" word. The test word is "Old" if you recognize it as belonging to the study list. Otherwise, the test word is "New".

Here are the exact steps for the recognition test. First, the computer will display the message, "Get ready for the test." At this time, place your index fingers on the red and green buttons, labeled "Old" and "New," and one thumb on the space bar. Please note which button is the "Old" button and which button is the "New" button. Press the space bar, when you are ready to begin the test.

After you press the space bar, the computer displays a fixation point. Look directly at the fixation point. Next, the cue word appears briefly. Read this cue word and get ready for the test word. When the computer displays the test word, press the "Old" button if you recognize the word as one belonging to the study list. **YOU SHOULD ANSWER "OLD" EVEN WHEN THE TEST WORD COMES FROM A DIFFERENT WORD GROUP THAN THE CUE WORD.** Press the "New" button, however, if you do not recognize the word as one from the study list. Please make your decision about each test word as quickly and accurately as possible. I will not tell you whether you have made a correct choice, but, all decisions that take longer than 3 seconds are incorrect. Once you have made a decision, get ready for the next clue-word-test-word pair. When the final test word disappears, get ready to study and rate the next list of words.

In summary, there are three tasks for you to carry out. First, learn each word group by combining the words into interacting mental images. Second, rate the cohesiveness or completeness of the image you create. Third, identify the "Old" words from the study list.

Finally, feel free to reread these instructions. Once you have read the instructions, please raise your hand briefly to tell me that you are ready to begin. Please wait for my signal before you start the experiment. While you are waiting, rehearse the steps in the study-test procedure and prepare to ask me any questions you have about the procedure. I will give you a chance to ask these questions before we begin.

Appendix D

DESIGN FOR EXPERIMENT 1

DESIGN FOR EXPERIMENT 1

Sbjcts	Pos 1			Pos 2			Pos 3			Pos 4			Pos 5			Pos 6			*Verbal Set*		
S01	A1	A2	A3	A1	A2	A3	A1	A2	A3	A1	A2	A3	A1	A2	A3	A1	A2	A3	A1	A2	A3
Grp 1 : B1	4	1	2	34	31	32	16	13	14	10	7	8	28	25	26	22	19	20	*d*	*a*	*b*
S06 B2	5	6	3	35	36	33	17	18	15	11	12	9	29	30	27	23	24	21	*e*	*f*	*c*
Trial Set		***1***			***6***			***3***			***2***			***5***			***4***				
S07																					
Grp 2 : B1	30	29	25	12	11	7	24	23	19	6	5	1	18	17	13	36	35	31	*f*	*e*	*a*
S12 B2	26	27	28	8	9	10	20	21	22	2	3	4	14	15	16	32	33	34	*b*	*c*	*d*
Trial Set		***5***			***2***			***4***			***1***			***3***			***6***				
S13																					
Grp 3 : B1	13	14	15	25	26	27	31	32	33	19	20	21	1	2	3	7	8	9	*a*	*b*	*c*
S18 B2	18	16	17	30	28	29	36	34	35	24	22	23	6	4	5	12	10	11	*f*	*d*	*e*
Trial Set		***3***			***5***			***6***			***4***			***1***			***2***				
S19																					
Grp 4 : B1	11	10	12	5	4	6	29	28	30	35	34	36	23	22	24	17	16	18	*e*	*d*	*f*
S24 B2	9	7	8	3	1	2	27	25	26	33	31	32	21	19	20	15	13	14	*c*	*a*	*b*
Trial Set		***2***			***1***			***5***			***6***			***4***			***3***				
S25																					
Grp 5 : B1	32	33	34	20	21	22	2	3	4	14	15	16	8	9	10	26	27	28	*b*	*c*	*d*
S30 B2	31	35	36	19	23	24	1	5	6	13	17	18	7	11	12	25	29	30	*a*	*e*	*f*
Trial Set		***6***			***4***			***1***			***3***			***2***			***5***				
S31																					
Grp 6 : B1	21	24	23	15	18	17	9	12	11	27	30	29	33	36	35	3	6	5	c	f	e
S36 B2	22	20	19	16	14	13	10	8	7	28	26	25	34	32	31	4	2	1	*d*	*b*	*a*
Trial Set		***4***			***3***			***2***			***5***			***6***			***1***				

See the next page for notes.

NOTES TO THE DESIGN FOR EXPERIMENT 1

Grp = Group

Pos = List Position of Trial Set

Treatments (AB)
- A = Storage Unit Size
  - A1 = 2
  - A2 = 3
  - A4 = 4
- B = Context
  - B1 = Same
  - B2 = Different

- The numbers under the AB treatment combinations refer to target numbers.
- A verbal set is a set of targets that are rotated through the AB treatment combinations.

  Example: Verbal Set *d* = targets 4, 10, 16, 22, 28, 34 and appear in the A1B1 treatment for the Group 1 participants.

Appendix E

ANALYSIS OF VARIANCE TABLES [17]

[17] The counterbalancing arrangements used in the experimental design permits a complex analysis that extracts two latin square error terms. One square involves the variables group, verbal set, and experimental condition (i.e., treatment); whereas the second square involves group, position, and trial set. To simplify the presentation of the analysis, however, the analysis of variance tables in this appendix are for an analysis that includes only the first of these latin square error terms. Presenting this simpler version of the analysis seems justifiable because the interpretation of the results is unaltered by the more complex analysis.

E1. Experiment 1

Analysis of variance for the cohesionn rating data in Experiment 1

Source	*df*	*SS*	*MS*	F_1	F_2
Between Subjects	35	1055.45582			
G (groups)	5	114.66763	22.93353	<1	-
Subj w. G	30	940.78819	31.35961		
Between Items	35	36.84472			
V (verbal sets)	5	3.92458	0.78492	-	<1
Items w. V	30	32.92014	1.09734		
Within	1225	705.82890			
S (storage unit size)	2	50.80131	25.40066	28.88	28.04
*S*Subj w. G*	60	52.76389	0.87940		
*S*Items w. V*	60	54.36111	0.90602		
L. S. Error	20	21.83951	1.09198		
Residual	1083	526.06308	0.48575		
Total	1295	1798.12944			

Note. The analysis of the cohesion rating data excludes the context variable. This was because context was not manipulated for these ratings, and, therefore, should add nothing more than random variation. Consequently, the residual error term absorbs the effects of context in this analysis.

Subjects random analysis for complete unit recall in Experiment 1

Source	df		SS		MS	F	p>F
Between Subjects		35		3.28351			
G (groups)		5		0.74083	0.14817	1.75	0.15
Subj w. G		30		2.54268	0.08476		
Within Subj		612		19.39680			
V (verbal sets)		5		0.09565	0.01913	1.31	0.26
T(treatments)		5		0.51957			
C (context)	1		0.01333		0.01333	0.72	0.40
S (storage unit size)	2		0.48169		0.24084	22.34	0.00
*C*S*	2		0.02455		0.01227	0.75	0.48
L. S. Error		20		0.80074	0.04004		
*T*Subj w. G*		150		2.18312			
*C*Subj w. G*	30		0.55423		0.01847		
*S*Subj w. G*	60		0.64683		0.01078		
*C*S*Subj w. G*	60		0.98206		0.01637		
Sn (session)		2		4.72855	2.36428	42.86	0.00
*G*Sn*		10		0.94822	0.09482	1.72	0.10
*Sn*Subj w. G*		60		3.30951	0.05516		
*V*Sn*		10		0.32460	0.03246	2.01	0.03
*T*Sn*		10		0.71485			
*C*Sn*	2		0.01670		0.00835	0.50	0.61
*S*Sn*	4		0.68207		0.17052	10.56	0.00
*C*S*Sn*	4		0.01608		0.00402	0.25	0.91
*L. S. Error*Sn*		40		0.92485	0.02312		
*T*Sn*Subj w. G*		300		4.84714			
*C*Sn*Subj w. G*	60		1.00971		0.01683		
*S*Sn*Subj w. G*	120		1.93805		0.01615		
*C*S*Sn*Subj w. G*	120		1.89938		0.01583		
Total		647		22.68031			

Item random analysis for complete unit recall in Experiment 1

Source	df	SS	MS	F	p>F
Between Items	35	1.15142			
V (verbal sets)	5	0.07568	0.01514	0.42	0.83
Items w. V	30	1.07574	0.03586		
Within Items	612	18.73716			
G (groups)	5	1.14370	0.22874	15.45	0.00
T(treatments)	5	0.72352			
C (context)	1	0.00001	0.00001	0.00	0.97
S (storage unit size)	2	0.68502	0.34251	22.68	0.00
*C*S*	2	0.03849	0.01925	1.09	0.34
L. S. Error	20	0.61463	0.03073		
*T*Items w. V*	150	2.22044			
*C*Items w. V*	30	0.25123	0.00837		
*S*Items w. V*	60	0.90598	0.01510		
*C*S*Items w. V*	60	1.06323	0.01772		
Sn (session)	2	5.85601	2.92801	178.95	0.00
*V*Sn*	10	0.27602	0.02760	1.69	0.10
*Sn*Items w. V*	60	0.98170	0.01636		
*G*Sn*	10	1.58251	0.15825	13.45	0.00
*T*Sn*	10	1.03673			
*C*Sn*	2	0.01284	0.00642	0.59	0.56
*S*Sn*	4	0.98474	0.24619	22.13	0.00
*C*S*Sn*	4	0.03915	0.00979	0.76	0.55
*L. S. Error*Sn*	40	0.77174	0.01929		
*T*Sn*Items w. V*	300	3.53016			
*C*Sn*Items w. V*	60	0.65221	0.01087		
*S*Sn*Items w. V*	120	1.33505	0.01113		
*C*S*Sn*Items w. V*	120	1.54290	0.01286		
Total	647	19.88858			

Subjects random analysis for items-per-unit recall in Experiment 1

Source	df	SS	MS	F	p>F
Between Subjects	35	14.56220			
G (groups)	5	4.06297	0.81259	2.32	0.07
Subj w. G	30	10.49923	0.34997		
Within Subj	612	417.28858			
V (verbal sets)	5	0.82120	0.16424	3.85	0.00
T(treatments)	5	349.18334			
C (context)	1	0.00724	0.00724	0.32	0.58
S (storage unit size)	2	349.10245	174.55123	3013.57	0.00
*C*S*	2	0.07365	0.03682	0.99	0.38
L. S. Error	20	2.64901	0.13245		
*T*Subj w. G*	150	6.39429			
*C*Subj w. G*	30	0.68133	0.02271		
*S*Subj w. G*	60	3.47531	0.05792		
*C*S*Subj w. G*	60	2.23765	0.03729		
Sn (session)	2	14.47385	7.23693	31.01	0.00
*Sn*G*	10	5.74374	0.57437	2.46	0.02
*Sn*Subj w. G*	60	14.00154	0.23336		
*V*Sn*	10	1.40989	0.14099	3.35	0.00
*T*Sn*	10	6.43973			
*C*Sn*	2	0.02992	0.01496	0.52	0.60
*S*Sn*	4	6.37286	1.59321	29.57	0.00
*C*S*Sn*	4	0.03695	0.00924	0.25	0.91
*L. S. Error*Sn*	40	3.55316	0.08883		
*T*Sn*Subj w. G*	300	12.61883			
*C*Sn*Subj w. G*	60	1.72994	0.02883		
*S*Sn*Subj w. G*	120	6.46605	0.05388		
*C*S*Sn*Subj w. G*	120	4.42284	0.03686		
Total	647	431.85078			

Item random analysis for items-per-unit recall in Experiment 1

Source	*df*	*SS*	*MS*	*F*	*p>F*
Between Items	35	3.65724			
V (verbal sets)	5	0.68707	0.13741	1.39	0.26
Items w. V	30	2.97017	0.09901		
Within Items	612	408.8241			
G (groups)	5	3.78481	0.75696	16.23	0.00
T(treatments)	5	351.28172			
C (context)	1	0.01715	0.01715	0.52	0.48
S (storage unit size)	2	351.19453	175.59726	3613.14	0.00
*C*S*	2	0.07004	0.03502	0.68	0.51
L. S. Error	20	2.59499	0.12975		
*T*Items w. V*	150	6.99589			
*C*Items w. V*	30	0.98657	0.03289		
*S*Items w. V*	60	2.91598	0.04860		
*C*S*Items w. V*	60	3.09334	0.05156		
Sn (session)	2	14.54331	7.27166	165.79	0.00
*V*Sn*	10	1.46391	0.14639	3.34	0.00
*Sn*Items w. V*	60	2.63169	0.04386		
*G*Sn*	10	5.80907	0.58091	18.04	0.00
*T*Sn*	10	6.46802			
*C*Sn*	2	0.01963	0.00982	0.31	0.74
*S*Sn*	4	6.40938	1.60234	53.85	0.00
*C*S*Sn*	4	0.03901	0.00975	0.28	0.89
*L. S. Error*Sn*	40	3.58916	0.08973		
*T*Sn*Items w. V*	300	9.66153			
*C*Sn*Items w. V*	60	1.90689	0.03178		
*S*Sn*Items w. V*	120	3.57041	0.02975		
*C*S*Sn*Items w. V*	120	4.18423	0.03487		
Total	647	412.48134			

Analysis of variance for response time data in Experiment 1

Source	*df*	*SS*	*MS*	F_1	F_2
Between Subjects	35	8.54464			
G (groups)	5	1.68875	0.33775	1.48	-
Subj w. G	30	6.85589	0.22853		
Between Items	35	1.31921			
V (verbal sets)	5	0.08154	0.01631	-	<1
Items w. V	30	1.23767	0.04126		
Within	1225	31.09169			
T(treatments)	5	3.91776			
C (context)	2	3.66064	3.66064	99.15	240.12
S (storage unit size)	1	0.22022	0.11011	5.11	3.76
*C*S*	2	0.03690	0.01845	<1	-
*T*Subj w. G*	150	3.78798			
*C*Subj w. G*	30	1.10763	0.03692		
*S*Subj w. G*	60	1.29284	0.02155		
*C*S*Subj w. G*	60	1.38751	0.02313		
*T*Items w. V*	150	4.53729			
*C*Items w. V*	30	0.45735	0.01525		
*S*Items w. V*	60	1.75866	0.02931		
*C*S*Items w. V*	60	2.32128	0.03869		
L. S. Error	20	0.53523	0.02676		
Residual	900	18.31343	0.02035		
Total	1295	40.95554			

Subjects random analysis for error data in Experiment 1

Source	*df*		*SS*		*MS*	*F*	*p>F*
Between Subjects		35		0.42954			
G (groups)		5		0.05240	0.01048	0.83	0.54
Subj w. G		30		0.37714	0.01257		
Within Subj		180		2.32584			
V (verbal sets)		5		0.08155	0.01631		
T(treatments)		5		0.36521			
C (context)	1		0.26136		0.26136	16.62	0.00
S (storage unit size)	2		0.04822		0.02411	2.76	0.07
*C*S*	2		0.05563		0.02782	3.24	0.05
L. S. Error		20		0.36835	0.01842		
*T*Subj w. G*		150		1.51073			
*C*Subj w. G*	30		0.47179		0.01573		
*S*Subj w. G*	60		0.52417		0.00874		
*C*S*Subj w. G*	60		0.51477		0.00858		
Total		215	2.75538				

Items random analysis for error data in Experiment 1

Source	df		SS		MS	F	p>F
Between Items		35		0.37310			
V (verbal sets)		5		0.03906	0.00781	0.28	0.92
Items w. V		30		0.33404	0.01113		
Within Items		180		3.46143			
G (groups)		5		0.01103	0.00221		
T(treatments)		5		0.40958			
C (context)	1		0.24056		0.24056	9.92	0.00
S (storage unit size)	2		0.04152		0.02076	1.27	0.29
*C*S*	2		0.12750		0.06375	4.86	0.01
L. S. Error		20		0.54888	0.02744		
*T*Items w. V*		150		2.49194			
*C*Items w. V*	30		0.72765		0.02426		
*S*Items w. V*	60		0.97723		0.01629		
*C*S*Items w. V*	60		0.78706		0.01312		
Total		215		3.83453			

Analysis of variance for lure response time data in Experiment 1

Source	*df*	*SS*	*MS*	*F*
Subj	35	0.10387	0.00297	
S (storage unit size)	2	0.00136	0.00068	<1
*S*Subj*	70	0.10557	0.00151	
Total	107	0.21080		

E2. EXPERIMENT 2[††]

Analysis of variance for the cohesion rating data in Experiment 2

Source	df	SS	MS	F_1	F_2
Between Subjects	107	5110.02675			
SOA	2	178.64751	89.32375	1.95	-
R (rows)	5	196.13709	39.22742	<1	-
*SOA*R*	10	610.47595	61.04760	1.33	-
*Subj w. SOA*R*	90	4124.76620	45.83074		
Between Items	35	193.47119			
V (verbal sets)	5	25.63246	5.12649	-	<1
Items w. V	30	167.83873	5.59462		
Within	3745	3729.69548			
S (storage unit size)	1	222.93236	222.93236	91.47	90.81
*S*Items w. V*	30	73.64429	2.45481		
*SOA*V*	10	11.35095	1.13510	-	1.67
*SOA*Items w. V*	60	40.69599	0.67827		
*SOA*S*	2	21.36741	10.68371	4.38	9.96
*S*Subj w. SOA*R*	90	219.34028	2.43711		
*SOA*S*Items w. V*	60	64.34414	1.07240		
L. S. Error	20	55.44573	2.77229		
*SOA*L. S. Error*	40	54.91152	1.37279		
Residual	3432	2965.66281	0.86412		
Total	3887	9033.19342			

Note. The analysis of the cohesion rating data excludes the context variable. This was because context was not manipulated for these ratings, and, therefore, should add nothing more than random variation. Consequently, the residual error term absorbs the effects of context in this analysis.

[††] The design of Experiment 2 nested groups of participants within the levels of SOA, and the analysis partitioned this source of variation as follows:

Source of Variation	df	
Groups within SOA		15
R (rows)	5	
*SOA*R*	10	

The row factor was a blocking factor that accounted for the same counterbalancing arrangement used for different groups of participants across the levels of SOA. Thus, each level of the row factor represented the sum of the observations for the groups that were treated alike across the levels of SOA (See Winer, 1969).

Subjects random analysis for complete unit recall data in Experiment 2

Source	df	SS	MS	F	p>F
Between Subjects	107	13.32239			
SOA	2	0.15496	0.07748	0.58	0.56
R (rows)	5	0.16926	0.03385	0.26	0.94
*SOA*R*	10	1.05432	0.10543	0.79	0.63
*Subj w. SOA*R*	90	11.94385	0.13271		
Within Subj	1836	40.55435			
V (verbal sets)	5	0.13811	0.02762	1.73	0.13
T(treatments)	5	1.62343			
C (context)	2	0.22475	0.11238	7.86	0.01
S (storage unit size)	1	1.39072	1.39072	50.53	0.00
*C*S*	2	0.00796	0.00398	0.34	0.71
*SOA*V*	10	0.20428	0.02043	1.28	0.24
*SOA*T*	10	0.06773			
*SOA*C*	4	0.02073	0.00518	0.36	0.84
*SOA*S*	2	0.01804	0.00902	0.33	0.72
*SOA*C*S*	4	0.02896	0.00724	0.61	0.65
*T*Subj w. SOA*R*	450	7.17861			
*C*Subj w. SOA*R*	180	2.57454	0.01430		
*S*Subj w. SOA*R*	90	2.47726	0.02753		
*C*S*Subj w. SOA*R*	180	2.12681	0.01182		
Sn(session)	2	9.05126	4.52563	106.17	0.00
*SOA*Sn*	4	0.07366	0.01842	0.43	0.79
*R*Sn*	10	0.17446	0.01745	0.41	0.94
*SOA*R*Sn*	20	0.55156	0.02758	0.65	0.87
*Sn*Subj w. SOA*R*	180	7.67277	0.04263		

Note. The table continues on the next page.

Subjects random analysis for complete unit recall data in Experiment 2—Continued

Source	df		SS		MS	F	p>F
*V*Sn*		10		0.19872	0.01987	1.83	0.05
*T*Sn*		10		1.17594			
*C*Sn*	4		0.18637		0.04659	4.53	0.00
*S*Sn*	2		0.94920		0.47460	40.10	0.00
*C*S*Sn*	4		0.04037		0.01009	0.93	0.45
*SOA*V*Sn*		20		0.19926	0.00996	0.92	0.56
*SOA*T*Sn*		20		0.10265			
*SOA*C*Sn*	8		0.02555		0.00319	0.31	0.96
*SOA*S*Sn*	4		0.02117		0.00529	0.45	0.77
*SOA*C*S*Sn*	8		0.05592		0.00699	0.64	0.74
*T*Sn*Subj w. SOA*R*		900		9.75811			
*C*Sn*Subj w. SOA*R*	360		3.70456		0.01029		
*S*Sn*Subj w. SOA*R*	180		2.13050		0.01184		
*C*S*Sn*Subj w. SOA*R*	360		3.92305		0.01090		
L. S. Error		20		0.41075	0.02054		
*SOA*L. S. Error*		40		0.52353	0.01309		
*Sn*L. S. Error*		40		0.62373	0.01559		
*SOA*Sn*L. S. Error*		80		0.82579	0.01032		
Total		1943		53.87674			

Items random analysis for complete unit recall data in Experiment 2

Source	df	SS	MS	F	p>F
Between Items	35	1.61285			
V (verbal sets)	5	0.25120	0.05024	1.11	0.38
Items w. V	30	1.36165	0.04539		
Within Items	1908	40.32534			
R (rows)	5	0.08711	0.01742	0.62	0.69
T(treatments)	5	1.89791			
C (context)	2	0.22878	0.11439	3.82	0.03
S (storage unit size)	1	1.65040	1.65040	41.53	0.00
*C*S*	2	0.01873	0.00937	0.45	0.64
*T*Items w. V*	150	4.23151			
*C*Items w. V*	60	1.79517	0.02992		
*S*Items w. V*	30	1.19208	0.03974		
*C*S*Items w. V*	60	1.24426	0.02074		
Sn(session)	2	9.97180	4.98590	255.91	0.00
*V*Sn*	10	0.33428	0.03343	1.72	0.10
*Sn*Items w. V*	60	1.16897	0.01948		
*R*Sn*	10	0.15085	0.01509	0.85	0.58
*T*Sn*	10	1.38438			
*C*Sn*	4	0.14963	0.03741	1.85	0.12
*S*Sn*	2	1.21589	0.60795	32.89	0.00
*C*S*Sn*	4	0.01886	0.00471	0.32	0.87
*T*Sn*Items w. V*	300	5.33313			
*C*Sn*Items w. V*	120	2.42992	0.02025		
*S*Sn*Items w. V*	60	1.10907	0.01848		
*C*S*Sn*Items w. V*	120	1.79414	0.01495		
SOA	2	0.16222	0.08111	9.49	0.00
*SOA*V*	10	0.08863	0.00886	1.04	0.42
*SOA*Items w. V*	60	0.51297	0.00855		

Note. The table continues on the next page.

Items random analysis for complete unit recall data in Experiment 2—Continued

Source	df	SS	MS	F	p>F
SOA*R	10	0.16351	0.01635	1.34	0.21
SOA*T	10	0.09326			
SOA*C	4	0.03140	0.00785	0.60	0.66
SOA*S	2	0.02751	0.01375	1.17	0.32
SOA*C*S	4	0.03435	0.00859	0.74	0.56
SOA*T*Items w. V	300	3.65139			
SOA*C*Items w. V	120	1.56341	0.01303		
SOA*S*Items w. V	60	0.70259	0.01171		
SOA*C*S*Items w. V	120	1.38539	0.01154		
SOA*Sn	4	0.06170	0.01543	1.72	0.15
SOA*V*Sn	20	0.16997	0.00850	0.95	0.53
SOA*Sn*Items w. V	120	1.07898	0.00899		
SOA*R*Sn	20	0.18337	0.00917	1.05	0.40
SOA*T*Sn	20	0.15571			
SOA*C*Sn	8	0.03827	0.00478	0.53	0.83
SOA*S*Sn	4	0.03392	0.00848	1.10	0.36
SOA*C*S*Sn	8	0.08352	0.01044	1.16	0.32
T*Sn*Items w. V	600	5.25138			
SOA*C*Sn*Items w. V	240	2.16820	0.00903		
SOA*S*Sn*Items w. V	120	0.92726	0.00773		
SOA*C*S*Sn*Items w. V	240	2.15592	0.00898		
L. S. Error	20	0.43184	0.02159		
Sn*L. S. Error	40	0.58519	0.01463		
SOA*L. S. Error	40	1.79633	0.04491		
SOA*Sn*L. S. Error	80	1.37895	0.01724		
Total	1943	41.93819			

Subjects random analysis for items-per-unit recall data in Experiment 2

Source	*df*	*SS*	*MS*	*F*	*p>F*
Between Subjects	107	21.54024			
SOA	2	0.16824	0.08412	0.39	0.68
R (rows)	5	0.24274	0.04855	0.22	0.95
*SOA*R*	10	1.67607	0.16761	0.78	0.65
*Subj w. SOA*R*	90	19.45319	0.21615		
Within Subj	1836	466.62345			
V (verbal sets)	5	0.25097	0.05019	1.48	0.20
T(treatments)	5	396.63677			
C (context)	2	0.32187	0.16094	7.28	0.01
S (storage unit size)	1	396.24423	396.24423	4537.40	0.00
*C*S*	2	0.07067	0.03534	1.83	0.16
*SOA*V*	10	0.31187	0.03119	0.92	0.52
*SOA*T*	10	0.23368			
*SOA*C*	4	0.07687	0.01922	0.87	0.48
*SOA*S*	2	0.05747	0.02874	0.33	0.72
*SOA*C*S*	4	0.09934	0.02483	1.29	0.28
*T*Subj w. SOA*R*	450	15.31224			
*C*Subj w. SOA*R*	180	3.98045	0.02211		
*S*Subj w. SOA*R*	90	7.85957	0.08733		
*C*S*Subj w. SOA*R*	180	3.47222	0.01929		
Sn(session)	2	13.12863	6.56431	80.96	0.00
*SOA*Sn*	4	0.04893	0.01223	0.15	0.96
*R*Sn*	10	0.32164	0.03216	0.40	0.95
*SOA*R*Sn*	20	1.17775	0.05889	0.73	0.80
*Sn*Subj w. SOA*R*	180	14.59465	0.08108		

Note. The table continues on the next page.

Subjects random analysis for items-per-unit recall data in Experiment 2—Continued

Source	*df*		*SS*		*MS*	*F*	*p>F*
*V*Sn*		10		0.34634	0.03463	1.97	0.03
*T*Sn*		10		4.20025			
*C*Sn*	4		0.27261		0.06815	5.50	0.00
*S*Sn*	2		3.85068		1.92534	54.43	0.00
*C*S*Sn*	4		0.07696		0.01924	1.39	0.24
*SOA*V*Sn*		20		0.31304	0.01565	0.89	0.60
*SOA*T*Sn*		20		0.29658			
*SOA*C*Sn*	8		0.09639		0.01205	0.97	0.46
*SOA*S*Sn*	4		0.03384		0.00846	0.24	0.92
*SOA*C*S*Sn*	8		0.16635		0.02079	1.50	0.16
*T*Sn*Subj w. SOA*R*		900		15.82510			
*C*Sn*Subj w. SOA*R*	360		4.46245		0.01240		
*S*Sn*Subj w. SOA*R*	180		6.36728		0.03537		
*C*S*Sn*Subj w. SOA*R*	360		4.99537		0.01388		
L. S. Error		20		0.53424	0.02671		
*SOA*L. S. Error*		40		0.95479	0.02387		
*Sn*L. S. Error*		40		0.82619	0.02065		
*SOA*Sn*L. S. Error*		80		1.30979	0.01637		
Total		1943		488.16369			

Items random analysis for items-per-unit recall data in Experiment 2

Source	df		SS		MS	F	p>F
Between Items		35		2.13489			
V (verbal sets)		5		0.21565	0.04313	0.67	0.65
Items w. V		30		1.91924	0.06397		
Within Items		1908		452.41772			
R (rows)		5		0.16421	0.03284	0.83	0.53
T(treatments)		5		396.63670			
C (context)	2		0.32187		0.16094	4.04	0.02
S (storage unit size)	1		396.24416		396.24416	7646.23	0.00
*C*S*	2		0.07067		0.03534	1.08	0.35
*T*Items w. V*		150		5.91926			
*C*Items w. V*	60		2.39244		0.03987		
*S*Items w. V*	30		1.55467		0.05182		
*C*S*Items w. V*	60		1.97215		0.03287		
Sn(session)		2		13.12865	6.56433	237.56	0.00
*V*Sn*		10		0.35337	0.03534	1.28	0.26
*Sn*Items w. V*		60		1.65792	0.02763		
*R*Sn*		10		0.25666	0.02567	1.09	0.37
*T*Sn*		10		4.20025			
*C*Sn*	4		0.27261		0.06815	2.59	0.04
*S*Sn*	2		3.85068		1.92534	64.19	0.00
*C*S*Sn*	4		0.07696		0.01924	1.08	0.37
*T*Sn*Items w. V*		300		7.08539			
*C*Sn*Items w. V*	120		3.15392		0.02628		
*S*Sn*Items w. V*	60		1.79974		0.03000		
*C*S*Sn*Items w. V*	120		2.13173		0.01776		
SOA		2		0.16824	0.08412	6.18	0.00
*SOA*V*		10		0.16149	0.01615	1.19	0.32
*SOA*Items w. V*		60		0.81636	0.01361		

Note. The table continues on the next page.

Items random analysis for items-per-unit recall data in Experiment 2—Continued

Source	df		SS		MS	F	p>F
*SOA*R*		10		0.37137	0.03714	2.14	0.02
*SOA*T*		10		0.23368			
*SOA*C*	4		0.07687		0.01922	1.06	0.38
*SOA*S*	2		0.05747		0.02874	1.56	0.22
*SOA*C*S*	4		0.09934		0.02483	1.56	0.19
*SOA*T*Items w. V*		300		5.20320			
*SOA*C*Items w. V*	120		2.18482		0.01821		
*SOA*S*Items w. V*	60		1.10274		0.01838		
*SOA*C*S*Items w. V*	120		1.91564		0.01596		
*SOA*Sn*		4		0.04893	0.01223	0.90	0.47
*SOA*V*Sn*		20		0.28647	0.01432	1.05	0.41
*SOA*Sn*Items w. V*		120		1.63889	0.01366		
*SOA*R*Sn*		20		0.41301	0.02065	1.69	0.03
*SOA*T*Sn*		20		0.29658			
*SOA*C*Sn*	8		0.09639		0.01205	1.03	0.42
*SOA*S*Sn*	4		0.03384		0.00846	0.68	0.61
*SOA*C*S*Sn*	8		0.16635		0.02079	1.65	0.11
*T*Sn*Items w. V*		600		7.33387			
*SOA*C*Sn*Items w. V*	240		2.81974		0.01175		
*SOA*S*Sn*Items w. V*	120		1.49814		0.01248		
*SOA*C*S*Sn*Items w. V*	240		3.01599		0.01257		
L. S. Error		20		0.64809	0.03240		
*Sn*L. S. Error*		40		0.88415	0.02210		
*SOA*L. S. Error*		40		2.40987	0.06025		
*SOA*Sn*L. S. Error*		80		2.10111	0.02626		
Total		1943		454.55261			

Analysis of variance for response time data in Experiment 2

Source	df	SS	MS	F_1	F_2
Between Subjects	107	37.10235			
SOA	2	1.45651	0.72825	2.26	-
R (rows)	5	1.25779	0.25156	<1	-
*SOA*R*	10	5.39864	0.53986	1.68	-
*Subj w. SOA*R*	90	28.98941	0.32210		
Between Items	35	1.64187			
V (verbal sets)	5	0.11376	0.02275	-	<1
Items w. V	30	1.52811	0.05094		
Within	3745	55.80193			
T(treatments)	5	8.24787			
C (context)	2	7.23893	3.61946	179.94	170.97
S (storage unit size)	1	0.96650	0.96650	66.06	50.85
*C*S*	2	0.04244	0.02122	2.12	-
*T*Items w. V*	150	4.13370			
*C*Items w. V*	60	1.27009	0.02117		
*S*Items w. V*	30	0.57017	0.01901		
*C*S*Items w. V*	60	2.29344	0.03822		
*SOA*V*	10	0.10526	0.01053	-	1.05
*SOA*Items w. V*	60	0.60353	0.01006		
*SOA*T*	10	0.23613	0.02361		
*SOA*C*	4	0.10320	0.02580	1.12	-
*SOA*S*	2	0.05189	0.02595	1.12	-
*SOA*C*S*	4	0.08104	0.02026	<1	-
*T*Subj w. SOA*R*	450	6.73671			
*C*Subj w. SOA*R*	180	3.62061	0.02011		
*S*Subj w. SOA*R*	90	1.31672	0.01463		
*C*S*Subj w. SOA*R*	180	1.79938	0.01000		
*SOA*T*Items w. V*	300	4.09042			
*SOA*C*Items w. V*	120	1.47095	0.01226		
*SOA*S*Items w. V*	60	0.68809	0.01147		
*SOA*C*S*Items w. V*	120	1.93138	0.01609		
L. S. Error	20	0.57033	0.02852		
*SOA*L. S. Error*	40	0.92459	0.02311		
Residual	2700	30.15339	0.01117		
Total	3887	94.54615			

Subjects random analysis for error data in Experiment 2

Source	df	SS	MS	F	p>F
Between Subjects	107	2.26568			
SOA	2	0.49200	0.24600	16.41	0.00
R (rows)	5	0.24735	0.04947	3.30	0.01
*SOA*R*	10	0.17750	0.01775	1.18	0.31
*Subj w. SOA*R*	90	1.34883	0.01499		
Within Subj	540	6.27795			
V (verbal sets)	5	0.06695	0.01339	1.29	0.27
T(treatments)	5	0.68694			
C (context)	2	0.40437	0.20218	16.97	0.00
S (storage unit size)	1	0.23148	0.23148	24.30	0.00
*C*S*	2	0.05109	0.02554	2.73	0.07
*SOA*V*	10	0.06644	0.00664	0.64	0.78
*SOA*T*	10	0.18147			
*SOA*C*	4	0.08478	0.02120	1.78	0.13
*SOA*S*	2	0.08926	0.04463	4.69	0.01
*SOA*C*S*	4	0.00743	0.00186	0.20	0.94
*T*Subj w. SOA*R*	450	4.68619			
*C*Subj w. SOA*R*	180	2.14418	0.01191		
*S*Subj w. SOA*R*	90	0.85720	0.00952		
*C*S*Subj w. SOA*R*	180	1.68481	0.00936		
L. S. Error	20	0.21402	0.01070		
*SOA*L. S. Error*	40	0.37594	0.00940		
Total	647	8.54363			

Items random analysis for error data in Experiment 2

Source	*df*	*SS*	*MS*	*F*	*p>F*
Between Items	35	0.76812			
V (verbal sets)	5	0.06988	0.01398	0.60	0.70
Items w. V	30	0.69824	0.02327		
Within Items	612	8.67714			
R (rows)	5	0.23698	0.04740	3.03	0.01
T(treatments)	5	0.67596			
C (context)	2	0.39602	0.19801	13.81	0.00
S (storage unit size)	1	0.22640	0.22640	18.90	0.00
*C*S*	2	0.05354	0.02677	1.43	0.25
*T*Items w. V*	150	2.34371			
*C*Items w. V*	60	0.86032	0.01434		
*S*Items w. V*	30	0.35944	0.01198		
*C*S*Items w. V*	60	1.12395	0.01873		
SOA	2	0.47316	0.23658	17.16	0.00
*SOA*V*	10	0.06581	0.00658	0.48	0.90
*SOA*Items w. V*	60	0.82712	0.01379		
*SOA*R*	10	0.17699	0.01770	1.70	0.08
*SOA*T*	10	0.17296			
*SOA*C*	4	0.08159	0.02040	2.09	0.09
*SOA*S*	2	0.08644	0.04322	4.25	0.02
*SOA*C*S*	4	0.00493	0.00123	0.11	0.98
*SOA*T*Items w. V*	300	3.12145			
*SOA*C*Items w. V*	120	1.17379	0.00978		
*SOA*S*Items w. V*	60	0.61015	0.01017		
*SOA*C*S*Items w. V*	120	1.33751	0.01115		
L. S. Error	20	0.21143	0.01057		
*SOA*L. S. Error*	40	0.37157	0.00929		
Total	647	9.44526			

Analysis of variance for lure response time data in Experiment 2

Source	*df*	*SS*	*MS*	*F*
Between Subjects	107	2.19802		
SOA	2	0.03770	0.01885	<1
Subj w. SOA	105	2.16032	0.02057	
Within Subj	108	0.08086		
S(storage unit size)	1	0.00044	0.00044	<1
*SOA*S*	2	0.00018	0.00009	<1
*S*Subj w. SOA*	105	0.08024	0.00076	
Total	215	2.27888		

Appendix F

MODEL, EXPECTED MEAN SQUARES, AND ASSUMPTIONS FOR THE ANALYSIS OF RESPONSE TIME DATA IN EXPERIMENT 1

F1. Model

$$x_{ijlmop} = \mu + \gamma_i + \pi_{j(i)} + \upsilon_l + \iota_{m(l)} + \alpha_o + \beta_p + \alpha\beta_{op} + \alpha\pi_{oj(i)} + \beta\pi_{pj(i)} + \alpha\beta\pi_{opj(i)}$$
$$+ \alpha\iota_{om(l)} + \beta\iota_{pm(l)} + \alpha\beta\iota_{opm(l)} + \gamma\upsilon'_{il} + \varepsilon_{j(i)m(l)op}$$

where

γ_i	= Group (G)	$i = 1,\ldots,6$
$\pi_{j(i)}$	= Subject (Subj)	$j = 1,\ldots,6$
υ_l	= Verbal Set (V)	$l = 1,\ldots,6$
$\iota_{m(l)}$	= Item (I)	$m = 1,\ldots,6$
α_o	= Context (C)	$o = 1,2$
β_p	= Storage Unit Size (S)	$p = 1,2,3$
$\gamma\upsilon'_{il}$	= Latin Square Error (G, V, C * S).	

The restrictions on the model are:

$$\gamma_i \sim \text{IIDN}(0,\sigma_\gamma^2) \quad \pi_{j(i)} \sim \text{IIDN}(0,\sigma_\pi^2) \quad \upsilon_l \sim \text{IIDN}(0,\sigma_\upsilon^2) \quad \iota_{m(l)} \sim \text{IIDN}(0,\sigma_\iota^2)$$
$$\sum_o \alpha_o = 0 \qquad \sum_p \beta_p = 0 \qquad \sum_{op} \alpha\beta_{op} = 0$$
$$\alpha\pi_{oj(i)} \sim \text{IIDN}(0,\sigma_{\alpha\pi}^2) \quad \beta\pi_{pj(i)} \sim \text{IIDN}(0,\sigma_{\beta\pi}^2) \quad \alpha\beta\pi_{opj(i)} \sim \text{IIDN}(0,\sigma_{\alpha\beta\pi}^2)$$
$$\alpha\iota_{om(l)} \sim \text{IIDN}(0,\sigma_{\alpha\iota}^2) \quad \beta\pi_{pm(l)} \sim \text{IIDN}(0,\sigma_{\beta\iota}^2) \quad \alpha\beta\pi_{opm(l)} \sim \text{IIDN}(0,\sigma_{\alpha\beta\iota}^2)$$
$$\gamma\iota'_{il} \sim \text{IIDN}(0,\sigma_{\gamma\iota'}^2) \qquad \varepsilon_{j(i)m(l)op} \sim \text{IIDN}(0,\sigma_\varepsilon^2).$$

Note. IIDN = independently, identically, and normally.

F2. Expected Mean Squares

Source of variation	df		Expected value of mean square
Between Subjects	35		
G (groups)		5	$\sigma_\varepsilon^2 + 36\sigma_\pi^2 + 216\sigma_\gamma^2$
Subj w. G		30	$\sigma_\varepsilon^2 + 36\sigma_\pi^2$
Between Items	35		
V (verbal sets)		5	$\sigma_\varepsilon^2 + 36\sigma_\iota^2 + 216\sigma_\upsilon^2$
Items w. V		30	$\sigma_\varepsilon^2 + 36\sigma_\iota^2$
Within	1225		
T(treatments)	5		
C (contest)		1	$\sigma_\varepsilon^2 + 18\sigma_{\alpha\iota}^2 + 18\sigma_{\alpha\pi}^2 + 648\sigma_\alpha^2$
S (storage unit size)		2	$\sigma_\varepsilon^2 + 12\sigma_{\beta\iota}^2 + 12\sigma_{\beta\pi}^2 + 432\sigma_\beta^2$
*C*S*		2	$\sigma_\varepsilon^2 + 6\sigma_{\alpha\beta\iota}^2 + 6\sigma_{\alpha\beta\pi}^2 + 216\sigma_{\alpha\beta}^2$
Subject Error Terms	150		
*C*Subj w. G*		30	$\sigma_\varepsilon^2 + 18\sigma_{\alpha\pi}^2$
*S*Subj w. G*		60	$\sigma_\varepsilon^2 + 12\sigma_{\beta\pi}^2$
*C*S*Subj w. G*		60	$\sigma_\varepsilon^2 + 6\sigma_{\alpha\beta\pi}^2$
Item Error Terms	150		
*C*Items w. V*		30	$\sigma_\varepsilon^2 + 18\sigma_{\alpha\iota}^2$
*S*Items w. V*		60	$\sigma_\varepsilon^2 + 12\sigma_{\beta\iota}^2$
*C*S*Items w. V*		60	$\sigma_\varepsilon^2 + 6\sigma_{\alpha\beta\iota}^2$
L.S. Error		20	$\sigma_\varepsilon^2 + 36\sigma_{\gamma\prime}^2$
Error		900	σ_ε^2
Total		1295	

F3. ASSUMPTIONS

The counterbalancing arrangement in the design of the experiment furnishes the design with qualities of a Latin square design. As a consequence of these qualities, the design of the experiment has many of the advantages of a Latin square design. One advantage is that the Latin square permits the investigation of several variables with less time, participants, and material than a complete factorial design. A second advantage is that the Latin square design is more efficient than other designs. This means that the error term for testing treatment effects tends to be smaller in the Latin square design than in other designs.

As with all things, potential advantages also bring potential disadvantages. One disadvantage is that interactions between the factors that form a Latin square can complicate the interpretation of the treatment effects. These interactions complicate the interpretation because the interactions are partially confounded with main effects.

In view of the possibility for confounding, the researcher must make a decision about the presence of interactions. The decision is an important one because it represents a set of assumptions about how to test and interpret the treatment effects. One decision is to assume that interactions are present and then to decide which factors interact. Once this decision has been made, then appropriate error terms can often be selected to test the treatment effects. What this means is that one or more of the treatment effects will be tested against the Latin square error term rather than the customary experimental error term. The rationale for this test against the Latin square error is that the Latin square error will include the interactions that are confounded with the treatment effect, and provide an unbiased test of the treatment effect. A consequence of being wrong with this set of assumptions is that the tests of treatments can be *negatively biased*. This means that the test loses its ability to reject the null hypothesis when there is a treatment effect (i.e., power is lost).

The other decision is to assume that interactions between the factors that form the Latin square are negligible and to test the treatment effects against the experimental error term. While this assumption simplifies the decision making process considerably, there is a consequence for being wrong with this assumption as well. The consequence is that the test of a treatment effect can be *positively biased*. This means that too many Type 1 errors are made.

In the design of the research at hand, the factors group, verbal set and treatment (i.e., the six combinations of storage unit size and context) formed a Latin square. To help simplify the selection of appropriate error terms for the test of treatment effects, interactions between the group, verbal set and treatment factors were assumed negligible.

The interested reader is referred to Myers (1972) and Winer (1962) for more thorough discussion of the analysis of Latin square designs. Also worth reading is Pollatsek and Well (1995) who focus on the analysis of counterbalanced designs in cognitive psychology.

Appendix G

EQUATIONS FOR F'' AND MIN F'

EQUATIONS FOR F" AND MIN F'

G1.

$$F''(i,j) = \frac{(MSE_T + MSE_{PxIw.G})}{(MSE_{TxPw.G} + MSE_{TxIw.V})} \quad (1)$$

$$i = \frac{(MSE_1 + MSE_2)^2}{\left(\frac{MSE_1^{\ 2}}{n_1} + \frac{MSE_2^{\ 2}}{n_2}\right)} \quad (2)$$

where n_1 and n_2 are the degrees of freedom for MSE_1 and MSE_2 from the numerator in Equation 1. The degrees of freedom j use the denominator $MSEs$ and are calculated the same way as the degrees of freedom for i.

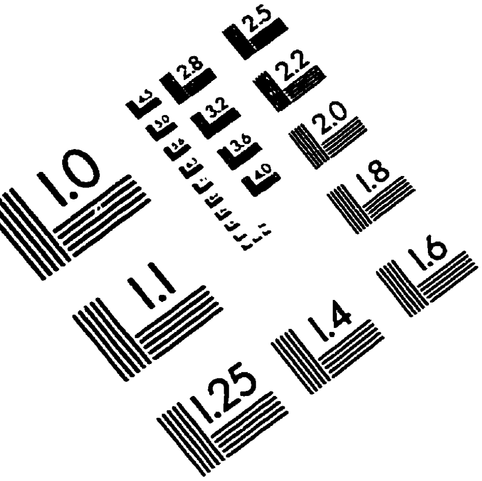
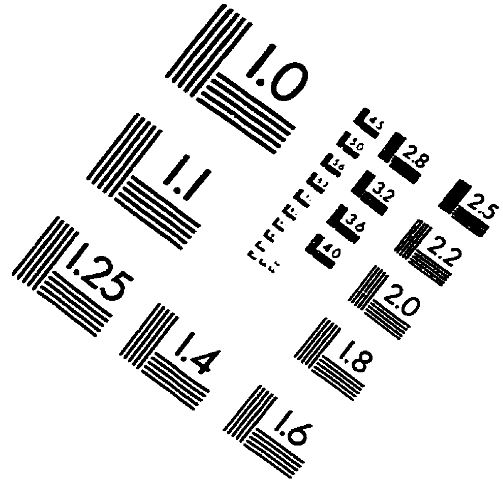
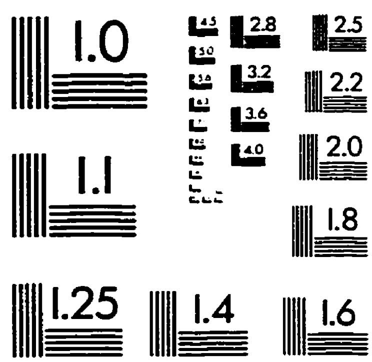
G2.

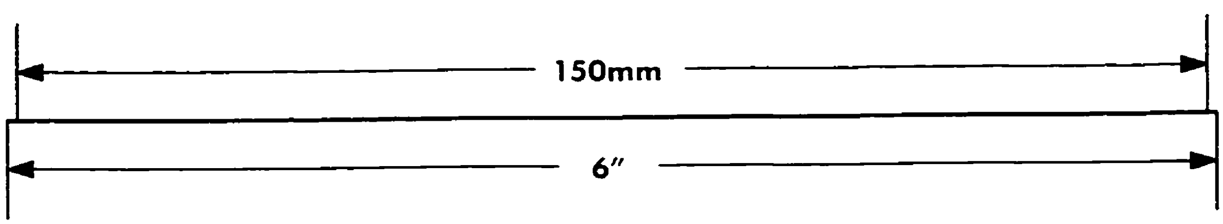
$$\min F'(i,j) = F_1 F_2 / (F_1 + F_2) \quad (3)$$

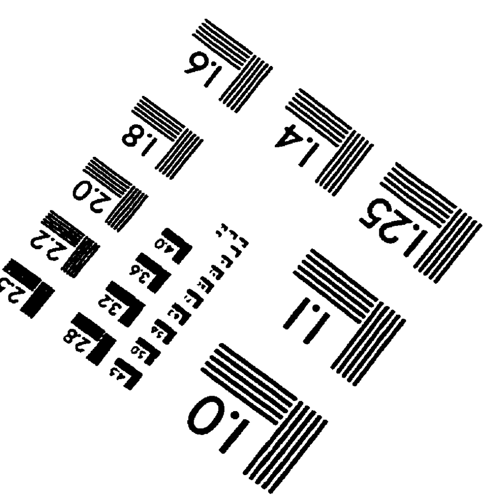
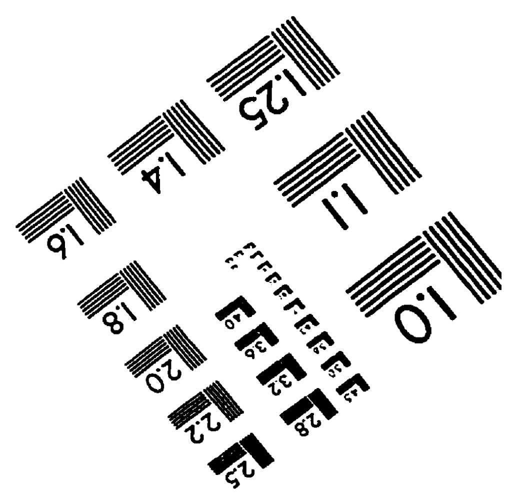
$$j = (F_1 + F_2)^2 \Big/ \left(F_1^2 / n_2 + F_2^2 / n_1 \right) \quad (4)$$

$i = n$ where n is the degrees of freedom for the numerator F_1 and F_2.

IMAGE EVALUATION TEST TARGET (QA-3)



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