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Context and distinctiveness in memory: Evidence for a two-stage process of recall

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Evidence for a Two-Stage Process of Recall

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ABSTRACT

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Evidence for a Two-Stage Process of Recall

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Whenever a task requires selecting a subset of items, a common sorting strategy involves dividing the process into two stages: during the first stage, a coarse preliminary search reduces the number of items to be examined, and in the second, a more detailed search determines the final selection. A coarse-detailed process (CDP) theory of recall is described which accounts for recall of items from memory. Two criteria for searching—processing context in the first stage and distinctiveness in the second—are proposed. The theory assumes that when people recall a list of items, they first assemble a pool of candidates based on knowledge of what the target items should be like. One method of doing this is to reinstate the processes used when the items were originally experienced. During the second stage, which is independent of the first, the pool of candidates is examined in a more detailed search to determine final selection. At this point, the more distinctive the item, the greater the probability of selection. Five experiments test predictions of this processing-based model using the continual-distractor paradigm, where each to-be-remembered word is followed by some activity designed to minimize rehearsal. The processing contexts of the items were manipulated by altering which activity followed each item. The probability of recalling an item was reduced when that item had a unique processing context; this reduction occurred regardless of whether subjects expected a recall test. The final experiment demonstrated that context and distinctiveness can operate simultaneously but independently. The results favor the CDP theory, illustrating that the processing context of an item can serve as a basis for creating a pool of candidates, and that the distinctiveness of the item can then serve to increase its chances of being recalled.
to my parents
"Memories, like perceptions and eventually sensations, have no separate existences. The memory of what you saw yesterday has no more existence until revived than the pain you felt in your arm before it was pinched... In short, for the experiencing individual, memories do not exist before they are revived or recalled. Memories are not like filed letters stored in cabinets or unhung paintings in the basement of a museum. Rather, they are like melodies realized by striking the keys on a piano. Ideas are no more stored in the brain than melodies in the keys of the piano."

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INTRODUCTION

Whenever people try to recall some item or an episode, they become subject to perhaps the most ubiquitous effect of memory: they generally remember what happened most recently better than what happened earlier. This remarkably pervasive recency effect appears in the young (Samuel, 1978), the elderly (Arenberg, 1976), and across the range of IQs (Glanzer, 1972); occurs across cultures (Wagner, 1978) and species (Hitch, 1984, 1985; Wright, Santiago, Sands, Kendrick, & Cook, 1985); resists disruption from alcohol (Baddeley, 1981) and certain types of brain damage (Cermak, 1982; Parkinson, 1982); and even materializes in such everyday events as recalling the games played by a rugby team during a season (Baddeley & Hitch, 1977) or the space in which you parked your car (Pinto & Baddeley, 1986). Because of the prevalence of this effect, many theories of recency have served as the basis for more general theories of memory and experiments manipulating the degree of recency have often played a role in supporting or disconfirming the more general theories.

Several researchers have developed theories of memory centered around the idea of some form of distinctiveness (e.g., Glenberg & Swanson, 1986; Johnson, 1991; Neath & Crowder, 1990). In these theories, remembering is compared to visual perception, an idea previously proposed by Aristotle, Aquinas, Hobbes, and Condillac amongst others (Burnham, 1888). The central assumption is that the more distinctive an item, the more likely it will be correctly recalled, and so any experiment which demonstrates lower recall of a presumably more distinctive item poses a serious problem for this class of theories. Koppenaal and Glanzer (1990) reported just such a finding while studying the recency effect.

The recency effect reflects the better recall of the last few items in a list compared to items earlier in the list. When the list is followed by a period of distracting activity, the recency effect either disappears or is significantly attenuated (Glanzer & Cunitz, 1966). If, however, the distracting activity appears after every item, the recency effect reemerges (Bjork
& Whitten, 1974). That is, a distractor task sufficient to remove the recency effect when applied at the end of a conventional list does not do so when applied after each and every item.

Koppenaal and Glanzer (1990) modified this continual-distractor paradigm so that the nature of the distractor task changed during list presentation. For example, in a list of twelve items, the first eleven words might be followed by one distractor task (solving addition problems) but the final item would be followed by a different distractor task (performing a short memory-span task). One might think that this change in distractor task would enhance the distinctiveness of the final item because its unique distracting activity renders it different from the other items in the list, as in the von Restorff or isolation effect: when an item in a list is made more distinctive in some fashion, such as presenting it in red ink when all other items are presented in black ink, recall of that item is greatly enhanced (von Restorff, 1933). But changing the distractor task reliably reduces recall of the final item. This changing-distractor effect, Koppenaal and Glanzer (1990) argued, supports a class of theories based on the modal model or dual-store theory of memory (e.g., Atkinson & Shiffrin, 1968; Glanzer, 1972; Waugh & Norman, 1965).

The Modal Model

Within the general framework of the modal model, the recency effect and related list effects are explained and accounted for by assuming that memory consists of a relatively permanent, unlimited long-term store (LTS) and a more labile, limited capacity short-term store (STS). The first few items in a list are sufficiently well rehearsed that they are transferred from STS to LTS, from which they can be recalled later with high accuracy; this produces the primacy effect. The items in the middle of the list, however, do not receive enough rehearsal while in STS to qualify for transfer to LTS and, furthermore, they are displaced from STS by the arrival of subsequent items; recall of middle items is poor. The items at the end of the list are not transferred to LTS either, but they remain undisturbed in STS because, by definition, no subsequent input follows them. Because nothing arrives to
displace them, recency items are well recalled.

The theory is supported, amongst other findings, by evidence that when an irrelevant distracting activity is added after the final item in order to 'occupy' STS, the recency effect disappears but the primacy effect remains (Glanzer & Cunitz, 1966) and by evidence that the recency effect remains stable across variations in list length (Murdock, 1962; Postman & Phillips, 1965) and presentation rate (Glanzer, 1972; Murdock, 1962). Furthermore, Rundus (1971) demonstrated that the first few items receive the most rehearsal, with the remaining items receiving less until an asymptote is reached midway through the curve. The final items could be well recalled despite relatively little rehearsal by being 'dumped' from STS. The first few items are well recalled because they have been rehearsed sufficiently to transfer them to LTS.

Subjects in the continual-distractor paradigm, Koppenaal and Glanzer argued, learn to rehearse the to-be-remembered items and to perform the distracting activity simultaneously: they develop a multi-tasking ability, switching their processing back and forth from one activity to the other very quickly. In this way, subjects are able to maintain the final item in STS while still performing the distracting activity, resulting in the recency effect seen in lists with continual distraction. This ability develops over time with exposure to the distractor task: if the task changes within a list, the multi-tasking is disrupted and the item preceding the change cannot be rehearsed. Because the item is not rehearsed as much when the distractor task changes, the item cannot be transferred to LTS, is displaced from STS by the irrelevant material, and can no longer be recalled.

The CDP Model

Rather than proposing multiple stores, an alternate view, the CDP model (where 'C' stands for coarse, 'D' stands for detailed, and 'P' stands for process) proposes a two stage process to explain the recency, changing-distractor, and other serial position effects. Whenever a task requires selecting a subset of items, a common sorting strategy involves dividing the process into two stages: during the first stage, a coarse preliminary search
reduces the number of items to be examined, and in the second, a more detailed search determines the final selection. In terms of memory, when people come to recall a list of items, their first major task is to separate plausible from implausible candidates, a process analogous to a coarse search. Once a limited search set has been created, the items can be examined in more detail in order to determine which items to actually recall. The experiments to be reported here will demonstrate how the processing context of an item can be used in the first stage and how the distinctiveness of an item can be utilized in the second.

The proposed CDP model is conceptually similar to the generate-recognize models of memory. While these models have also gone under the name of search, production, or retrieval instead of generate, and decision, discrimination, or edit rather than recognition, most of the instantiations assume words, concepts, and ideas are represented as nodes in an associative network (e.g., Anderson & Bower, 1972; Kintsch, 1970). The inability of this class of models to account for recognition failure of recallable words is well known and the interested reader is referred to Tulving (1983, Chapter 13) for a more complete treatment. Briefly, an encounter with a word during learning is assumed to add an occurrence tag to the node representing that word. During recall, a search generates a group of words and then a decision is made about whether the appropriate tag is present. In a test of recall, a word might not be recalled because its representation was not generated or because an incorrect decision was made after generation. In a recognition test, only the latter leads to an error and so recognition, in this formulation, can never be worse than recall.

Watkins and Gardiner (1979, p. 689) noted that “the power of the theory is largely attributable to the unambiguous manner in which the two hypothesized processes can be experimentally separated.” For example, because it is possible to generate an item and not recall it, the available-accessible distinction of Tulving and Pearlstone (1966) is a natural consequence. What is most germane for the present discussion is that the CDP theory of recall can achieve the same experimental separation of the two processes, but can also avoid
the storage-based assumptions which weaken the classic generate-recognize models. There are two critical differences between the two formulations: first, the CDP model assumes that items are generated by reinstating the processing that occurred during the initial exposure to the item rather than assuming, like the generate-recognize models, that the items are represented by nodes in a structured associative network that are modified by the addition of tags. Second, the CDP model assumes that a generate stage occurs for both recall and recognition tests. To make these distinctions between the two formulations more clear, the following sections discuss each stage of the CDP model in more detail, and then explain the rationale for assuming that generating occurs for both recall and recognition tests.

Context. During the first stage, candidates for recall are generated; one possible way of doing this is by knowledge of the item's processing context. The processing context of an item can be operationally defined as the period of activity immediately following the item in question. It is during this period that residual processing of the item is assumed to occur and, because the substrate of memory is assumed to be the residue of information processing, the task which occurs after an item will color memory for that item. This view assumes that people have some knowledge, or as Francis Bacon (Robertson, 1905, p. 168) called it, a prenotion, about the items they are trying to recall:

By Prenotion I mean a kind of cutting off of infinity of search. For when a man desires to recall anything into his memory, if he have no prenotion or perception of that he seeks, he seeks and strives and beats about hither and thither as if in infinite space. But if he have some prenotion, this infinity is at once cut off, and the memory ranges in a narrower compass; like the hunting of a deer within an enclosure.

The CDP theory assumes that people can use the processing originally performed on the item as a prenotion. Access to the original processing can be gained in a way similar to that proposed by Shepard (1984). He assumed that the perceptual/representational system can
be activated by stimuli originating from inside the organism as well as by stimuli originating from outside. Different activities, such as sensing, perceiving, dreaming, imagining, and thinking, he argues, are differentiated chiefly by the proportion of each type of activation present. For example, perceiving under favorable conditions may be entirely bottom-up whereas perceiving under ambiguous or suboptimal conditions may require an additional top-down component. Similarly, imagining may be characterized as engaging only top-down processes and not the lower, more concrete and richer sensory levels of the system. Imageless thought can be seen as engaging even fewer lower levels. Additional empirical support for this characterization of mental imagery as a form of reactivating some, but not the lowest levels, of the neural machinery used in perception is presented by Farah (1988) and Finke (1989). According to the CDP model, the act of remembering consists of reactivating the neural mechanisms used to originally process the stimulus. To the extent that the reactivation reinstates the appropriate neural machinery, the item will be re-experienced or remembered.

It has long been known that items are better recalled when the learning and testing contexts match (e.g., Carr, 1925; McGeoch, 1932, 1942). This encoding specificity hypothesis (Tulving & Thomson, 1973) applies to many different manipulations of context, including changing the location (Godden & Baddeley, 1975; Smith, Glenberg, & Bjork, 1978) or the ambient odor (Schab, 1990), or changing the pharmacological (Eich, 1989) or affective state (Bower, 1981) of the person. Moreover, it can be demonstrated with many different testing paradigms, including free recall, cued recall, serial recall, and recognition (see Tulving, 1983, for a review) and is found with manipulations of both context alpha, the environmental surrounds, and context beta, surrounding information that serves to clarify or alter the meaning of the item (Wickens, 1987). The processing context of an item can be affected by, or is sensitive to, all of these forms: the more similar the test context to the acquisition context, the more cues there are for establishing how the items were originally processed.
Two experiments by Watkins and his colleagues illustrate how context can serve as the basis for the preliminary coarse search. Watkins, Neath, and Sechler (1989) presented subjects with a series of 12-word lists with the instructions to recall as many of the words as they could in whatever order they wished. After the presentation of each word within a list, the subjects heard and immediately tried to reproduce a 9-item sequence of the digits 1 through 9. Not only did the recall of the 12 words reveal a reliable recency effect, but recall of each of the supraspan lists of digits also revealed a reliable recency effect. That is, for each list of 12 words, 13 recency effects were observed, one for the list of words and one for each of the 12 distractor lists.

Watkins and Peynircioglu (1983) also reported simultaneous multiple recency effects. In each trial, subjects were presented with a 45-item list consisting of an equal number of items from 3 different categories. Every third item was from the same category, and the possible categories were riddles, sounds, objects, favorites, quiz questions, or drawings. After each list had been presented, subjects were cued by category which items to recall first, which to recall second, and which to recall third. Watkins and Peynircioglu found that recency was just as pronounced when the category was interwoven with two other categories as when it was presented alone. Moreover, the category that was cued first always displayed the most recency regardless of whether it had occurred first, second, or third in the interwoven list.

Each time recall is required, people first generate a pool of candidates for recall. One way this can be accomplished is by performing a coarse search to determine which items were originally processed in the same manner. It is easy to see how riddles, drawings, and sounds could be processed sufficiently differently such that this could later serve as a basis for differentiation. These results, and others like them (e.g., Wishner, Shipley, & Hurvich, 1957), illustrate how items can be grouped for the purposes of recall so that only the plausible target items are selected as candidates.

William James (1890, p. 224) noted that “no state once gone can recur and be
identical with what it was before.” Many subtle changes, both in the environment and in the individual, can occur even when the test immediately follows the learning. It is not surprising, therefore, that the original processing state cannot be always reinstated perfectly without sometimes failing to include items that were actually presented (misses) and sometimes including items that were not presented (false alarms).

Distinctiveness. The second stage of recall, according to the CDP model, is not affected by context; rather, the more distinctive an item, the more likely it will be correctly recalled. It is during this stage that theories like those of Koffka (1935), Murdock (1960), Glenberg and Swanson (1986) and Neath and Crowder (1990) are relevant. Koffka (1935) was the first to develop a theory of memory based on distinctiveness. He assumed that the memory process is dynamic and that it reflects processes such as perception. As events are perceived, their traces are laid down by a continuously moving process. The result, which he called the trace column, is not unlike a tape recording where time becomes spatialized. The traces in the column are assumed to be subject to the same spatial grouping principles that determine visual phenomena: the most recent items, temporally, would be the most distinct just as in visual perception the closest items, spatially, would be the most distinct. For Koffka, the explanation for the better recall of more recent items and the gradual increase in forgetting over time is a direct consequence of the basic processes of memory. Examining the trace column when trying to recall is like examining a list of telephone poles: the closest, most recent items are the most distinct and hence the easiest to pick out.

Murdock (1960, p. 17) defined distinctiveness as the extent to which a given stimulus “stands out” from other stimuli. “The concept of distinctiveness refers to the relationship between a given stimulus and one or more comparison stimuli, and if there are no comparison stimuli the concept of distinctiveness is simply not applicable” (p. 21). He quantified his definition by choosing as his stimuli 1000 Hz tones of varying intensities and using the difference in physical energy to compute a distinctiveness score, which predicted with high accuracy subjects’ performance on an absolute judgment task. After establishing
the validity of his definition of distinctiveness for stimuli varying in one physical dimension, he extended the idea to cover lists of items varying in a different dimension; for lists of words, he assumed the relevant dimension to be temporal.

Glenberg and Swanson (1986) found evidence that increasing the temporal distinctiveness of one item in a list led to better recall of that item. Neath and Crowder (1990) extended this result by examining the temporal distinctiveness of all items in the list. They noted that in a typical recall test, the retention interval (the time between presentation and recall) is different for each item in the list. They extended an idea similar to Weber's law and applied it to the discriminability of items in a list. The resulting rule, called the extended ratio rule, states that the larger the ratio between the temporal interval separating a given item from the item directly preceding it to the total time until recall, the better the level of recall for that item. Another way of saying this is that the longer an item has to be remembered, the more distinct it has to be in order to be well recalled. When applied to the whole list, the extended ratio rule predicts that optimal overall recall will occur when all items have the same ratios. Notice that this also predicts that a list with more distracting material can exhibit better recall than a list with less distracting activity, providing that the periods of distractor activity are judiciously distributed; longer-lasting lists can be recalled with more accuracy than shorter lists.

While Neath and Crowder (1990) verified the predictions of the extended ratio rule and found evidence that increasing an item's temporal distinctiveness increases that item's probability of being correctly recalled, von Restorff (1933) found that increasing an item's physical distinctiveness similarly aids recall. Wallace (1965) lists 3 ways of inducing physical distinctiveness experimentally: (1) by performing an additional operation on an item, such as printing the item in red when all other items are printed in black; (2) by

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1 It is interesting to note that this equation, and particularly its predecessor the ratio rule, bares a striking resemblance to the forgetting equations developed by Ebbinghaus (1885, p. 78) and Wolfe (Burnham, 1888, p. 605).
including a different kind of item, such as a three-digit number when all other items are CVCs; or (3) by using equal numbers of two types of items in a list, but arranging their occurrence such that one item of the first type is embedded within several items of a second type. Each of these manipulations results in the isolation effect, the enhanced recall of an item, termed the isolate, differentiated in some fashion from a homogeneous background. The CDP model predicts that any such manipulation operates during the second stage, the detailed search.

Implications. An important assumption of the CDP theory concerns generation: not only does a generating stage occur for recall tests, but also for recognition tests. For a test of recall, the subject has to generate a pool of candidates according to how the items were originally processed, typically relying on internal cues to determine the original processing. For a test of recognition, the subject has the seeming advantage of already knowing what the pool of candidates is and should then have to perform only a detailed search. Closer analysis of the recognition test reveals more complexity, however, and emphasizes the importance of the interaction between the learning and testing phases. At acquisition, the to-be-tested item is processed in a particular way; at test, it is again processed. However, the processing at test time is externally driven and may be different from the original processing because of experimenter-induced changes in context or because of environmental differences. Thus, it may not be effective in reinstating the original processing. For example, it is more difficult to recognize a person in an unfamiliar than in a familiar setting. The problem, according to CDP theory, is that the reinstated processing does not match sufficiently well with the original processing to permit an accurate re-experiencing of the original event.

This raises the question of ease of reinstating the original processing. The CDP model assumes that three factors play a role: (1) the time interval since the original processing; (2) the number of different ways the original information was processed; and (3) the number of times the original information was processed. If the time interval is
relatively short, there will be, on average, fewer changes in context between acquisition and
test. The larger the number of different ways an item was originally processed, the greater
the chances of picking one of them when attempting to generate items during the coarse
search. The greater the number of times the original information was processed, the more
likely it is that the process will become more automatic.

The word-frequency effect addresses this issue and illustrates how in different
situations some of the criteria may be more important than at others. Typically, low-
frequency words are recognized better than they are recalled whereas high-frequency words
are recalled better than they are recognized. In Shepard's (1967) experiment, for example,
the high-frequency words were like ‘child’ and ‘office’ while the low-frequency words
were like ‘ferule’ and ‘wanled.’ For a test of recall, which requires an internally-driven
generating process, high-frequency words satisfy more of the ‘ease of reinstating’ criteria
listed above than do low-frequency words. By definition, high-frequency words are
processed more often and so the processing required for such an item has become more
automatic. Access to the original processing is therefore easier than for low-frequency
words and so high-frequency words are better recalled. In a test of recognition, however, an
externally-driven generating process is used. Because the test item is presented to the
person, the processing done during the test serves as the basis for the generating stage and it
matters little that the processing of low-frequency words is less automatic and less common
than for high-frequency words; in fact, this helps: once in the pool of candidates, low-
frequency words are generally less confusable with other items because they are more
distinct and so fewer errors will occur during the detailed stage. It is only when the
processing required at test time differs from that at learning that externally-driven generating
processes are disadvantaged (e.g., Tulving & Thomson, 1973).

In short, the CDP theory of recall states that processing context can serve as an
effective way of selecting an appropriate pool of candidates for recall (Watkins &
Peynircioglu, 1983; Watkins et al., 1989) and that after inclusion in the pool, candidates will
be selected according to a variety of post-selection principles including, for example, temporal distinctiveness (Neath & Crowder, 1990) and item distinctiveness (von Restorff, 1933).

OVERVIEW OF EXPERIMENTS

The five experiments reported here test several specific predictions and assumptions of the CDP model of recall. Experiment 1 tests the prediction that because the processing context can be accessed even when people are not specifically memorizing the items, a changing-distractor effect can be observed with incidental learning conditions. Experiment 2 tests the assumption that the likelihood of an item's being included in the set of plausible candidates depends upon the degree of similarity between the processing context of the item in question and the processing context of the other items: a condition where the context is only partly different should result in better recall than a condition where the context shares even fewer similarities. Experiment 3 tests an alternate explanation based on attention. If the changing-distractor effect is due to a shift of attention, then if the nature of the distractor effect changes after every item in the list, there should be an equal decrement at every serial position relative to a control condition.

Experiment 4 tests the generality of the process theory by demonstrating the changing-distractor effect at serial positions throughout the list. Finally, Experiment 5 compares the changing-distractor effect to the von Restorff effect, supplying evidence for the proposed two-stage theory of recall. The CDP theory assumes that context and distinctiveness operate independently; if this is so, then one should observe a changing-distractor effect regardless of whether an isolation manipulation is concurrently being performed, and also an isolation effect regardless of whether a changing-distractor manipulation is being made.

EXPERIMENT 1

Experiment 1 compares specific predictions of the model model and the CDP model. Koppenaal and Glanzer (1990) assume that the changing-distractor effect is a strategic
effect due to the fact that the subjects are aware that a memory test will ensue. While subjects can learn to time-share the rehearsal of the to-be-remembered item with the processing of the distractor task, they argue, the introduction of another distractor task disrupts this strategy and rehearsal of the final item suffers. This model predicts that if subjects are unaware that a memory test will follow presentation of the list, no changing-distractor effect will be observed because no recency effect will be found. If subjects are unaware that there will be a test of recall, then there should be no reason for them to rehearse and keep the final items in STS, nor should there be a need for them to develop the elaborate multi-tasking strategy. Without the active rehearsal, the distractor-task material should remove the to-be-remembered items from STS.

The CDP model, however, predicts both a recency effect and a changing-distractor effect. The recency effect will occur because after the pool of candidates is generated, recall is dependent upon how distinctive the to-be-remembered items are at the time of recall. The most recent items, temporally, will be the most distinct and will be recalled better than earlier items. The changing-distractor effect will occur because the final item in a changing-distractor list will have a different processing context from the other eleven items and will not be included in the pool of candidates as often as the other items.

Method

Subjects. One hundred Yale University undergraduates and members of the Yale University summer community participated either for course credit in introductory psychology classes or for pay. An additional subject's data were discarded for reasons listed below.

Materials and Design. The design was almost identical to that of Koppenaal and Glanzer's (1990) Experiment 1, except that subjects were unaware that they would be tested for recall of the words and thus received only 1 trial. For the math distractor task, subjects read aloud a three digit number (between 100 and 998), added 1 to it silently, and then said the resulting sum out loud. For the word distractor task, subjects simply read aloud word
pairs displayed on the screen. Each subject received 1 practice list and 1 experimental list, the practice list containing alternating distractor tasks but omitting any mention of a recall test. The four conditions were unchanging math, unchanging words, changing math, and changing words, where unchanging means that the specified distractor task occurred after every item and changing means that the specified distractor task appeared after every item except the final item, where the other task occurred. Subjects were randomly assigned to one of the four different conditions based on the order of arrival in the laboratory. None of the subjects had participated in any related experiments in this laboratory prior to their participation in this study. All materials were randomized by and presented on an Apple Macintosh Plus computer. The to-be-remembered words were shown for 2 seconds, as were the word pairs and math problems; there were 6 word pairs or math problems in each 12 second distracting period. Subjects were allowed as long as they required for written free recall.

Procedure. Upon arrival in the lab, the subjects were told that the experimenter was interested in what made people hesitate while reading aloud from a computer screen. They were told about the results from a first hesitation experiment (which did not exist) and that the experimenter was interested in the role of uncertainty and type style on hesitating. Because of this, they would see up to three different kinds of information (single words, word pairs, or numbers) presented in different fonts. In the case of words, whether presented singly or in pairs, they were to read them aloud as quickly and as clearly as they could. For the numbers, they were to do the same, with the additional requirement of adding 1 and then saying the result out loud also. Subjects were led to believe that they were being recorded and that the tapes would be analyzed for signs of hesitation and mispronunciation. After the conclusion of the practice list, they were told that they should follow any instructions which were displayed on the screen, and that the computer would tell them when the experiment was over. Immediately following the one experimental list, a message was displayed on the CRT telling the subject to recall the words which had been presented
alone in the middle of the screen. Compliance with the instructions was verified by listening to the subjects as they read the items during the experiment. Finally, subjects were thoroughly debriefed about the deception involved and were questioned about their thoughts on the experiment. Subjects were tested individually in a sound chamber and were allowed to adjust the CRT to a comfortable level of brightness.

Results

![Graph](image)

Figure 1: Mean number of words recalled after incidental learning as a function of serial position and condition from Experiment 1.

Not one subject guessed the true nature of the experiment. After the experiment, every subject stated that he/she did not realize or guess that a memory test would occur until told to recall the words and almost all volunteered this information before being explicitly

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2 In most of the experiments to be reported, the critical statistical tests occur after collapsing across several conditions. The analyses which justify doing this were performed first, chronologically, but are reported at the end of each result section.
questioned. One subject's data were discarded because, on reading the recall instructions, he came out of the booth and complained that the test was unfair as he had not been warned that he was supposed to remember the words.

While overall recall was very low, floor effects were not a problem for the final serial position where recall was substantially higher than zero. As Figure 1 illustrates, both a robust recency effect and a reliable changing-distractor effect can be obtained with an incidental learning procedure in the continual-distractor paradigm. The difference between the unchanging and changing conditions was reliable at position 12: $F(1,96) = 5.83, MSe = 0.21, p < .05$. Even though subjects were unaware that a recall test would follow list presentation, changing the context in which an item was processed reduced the probability that the item would be correctly recalled, as predicted by the CDP model.

The results of a 2 conditions (unchanging or changing distractor task) by 2 distractor tasks (math or word pairs) by 12 serial positions ANOVA supported the above conclusions. There was no main effect of condition ($F(1,96) = 2.72, MSe = .11, p > .10$), but the main effects of type of distractor task and of position were both reliable ($F(1,96) = 7.25, MSe = 0.11, p < .01$ and $F(11,1056) = 10.27, MSe = 0.11, p < .0001$, respectively). Subjects recalled more words overall when the math distractor task occurred than when the word pair task occurred. This is probably due to the similarity of stimuli in the word-pair distractor task and in the main recall task. However, there were no reliable interactions involving type of distractor task: for condition by distractor, $F(1,96) = 2.19, MSe = 0.11, p > .10$; for distractor by position, $F(11,1056) = 1.06, MSe = 0.11, p > .30$; and for the three-way interaction, $F < 1$.

The condition by position interaction was marginally reliable ($F(11,1056) = 1.64, MSe = .11, p < .10$), reflecting the observation that for the first few items in the list, recall was slightly higher in the unchanging condition than in the changing condition. The only position where this difference was reliable was at position 4 ($F(1,96) = 4.97, MSe = 0.72, p < .05$). However, dividing the list into two equal halves revealed a reliable main effect of
condition for positions 1 through 6 \( F(1,96) = 8.02, MSe = 0.05, p < .01 \) but not for positions 7 through 12 \( F(1,96) < 1 \).

Discussion

Experiment 1 demonstrated both a so-called long-term recency effect and a changing-distractor effect under incidental learning conditions in the continual-distractor paradigm. This result is predicted by the CDP model, but the opposite result (no recency and hence no changing-distractor effect) is predicted by the modal model. Without the distractor tasks, it would be possible to explain previous demonstrations of recency with incidental learning (see Greene, 1986) by assuming that while the subjects did not rehearse, there was no information to 'remove' the final items from STS. Experiment 1 featured 12 seconds of auditory distractor activity after the final item and a recency effect was still apparent. Moreover, with the assumption that when people need not remember events, they do not ordinarily rehearse and are unlikely to develop a complex and difficult time-sharing procedure so that they can rehearse, the results favor the CDP rather than the modal model.

The CDP model predicts the obtained result. When a person attempts to recall a list, a set of potential candidates is generated which share the same processing context as the target items. Because the final item in the changing condition does not share the same processing context, it is less likely to be included in the pool of candidates and hence less likely to be available for selection during the second stage.

EXPERIMENT 2

The CDP model assumes that the likelihood of an item's being included in the set of plausible candidates depends upon the degree of similarity between the processing context of the item in question and the processing context of the other items. Experiment 2 manipulated the degree of similarity by adding an extra condition to the Koppenaal and Glanzer (1990) paradigm, a condition where the change in the distractor task occurred halfway through the final period of distracting activity. There were three conditions, unchanging, partially changing, and changing. The first and third of these were similar to
the unchanging and changing conditions used in Experiment 1; in the second condition, the distractor task changed halfway through the final distractor period. According to the CDP model, recall at the final serial position in the partially-changing condition should be better than in the changing condition because half of the period has the same context as the rest of the items, and should be worse than in the unchanging condition because half of the interval has a different context from the rest of the items.

The modal model makes no clear-cut predictions. It could predict the same results as the CDP model does by assuming that any rehearsal will benefit recall. In the partially-changing condition, subjects could rehearse during the first half of the final period because they have adapted to the task and have developed their multi-tasking ability; even this limited rehearsal may be better than none at all. The modal model could also predict that recall in the partially changing condition should be equally as bad as in the changing condition: despite the fact that rehearsal could occur for half of the period, it might not be sufficient to transfer the item to LTS and the subsequent distractor activity in the second half of the period would remove the item from STS.

Method

Subjects. Twenty-nine Yale University undergraduates and members of the Yale University summer community participated either for course credit in introductory psychology classes or for pay. One additional subject’s data were discarded for not following instructions: he stated that he did not perform the distractor tasks because they prevented him from rehearsing.

Materials and Design. If the periods of distractor activity are divided into three parts representing (1) the first eleven intervals, (2) the first half of the twelfth period, and (3) the final half of the twelfth period, and the math distractor activity is termed M and the word-pair distractor activity is termed W, then the unchanging, partially-changing, and changing conditions may be enumerated as: M-M-M and W-W-W; M-M-W and W-W-M; and M-W-W and W-M-M. The math problems were of the form x + y + z = k where
x, y, and z were the digits 1 through 9 and k was the correct sum 50% of the time, and incorrect by plus or minus 1 50% of the time. The subject's task was to read the math problem aloud, ignoring the fact that sometimes the problems were true and other times false. The word-pair distractor task consisted of the presentation of two words which the subject read aloud. Each word pair and math problem was presented for two seconds and 6 word pairs or 6 math problems were presented between each to-be-remembered item. The to-be-remembered words, like the math problems and word pairs, were read aloud by the subject as they appeared on the CRT. All materials were presented on an Apple Macintosh Plus computer, which randomized the order of the conditions and of the words within the lists. Unlike Experiment 1, and like all remaining experiments, subjects were told to remember the critical words for the upcoming free recall test.

Procedure. Each subject was read instructions which stated that everything which appeared on the computer screen was to be read out loud. At the end of each list, the subject had 30 seconds in which to write down, in any order, the words that had been presented alone in the center of the screen. The subject then received 1 practice list in which the type of distractor activity changed halfway through each distractor period, ensuring equivalent exposure to the different materials. After any questions had been answered, the subject received 12 experimental lists, 2 from each condition, in a random order. Subjects were tested individually in a sound chamber and were permitted to adjust the CRT to a comfortable level of brightness. A microphone in the sound booth revealed that all stimuli were appropriately vocalized, and a closed-circuit video camera served as an electronic invigilator to ensure that subjects did not begin writing down words until the end of each list.

Results

As can be seen in Figure 2, performance in the unchanging and changing conditions at the final serial position replicated the basic changing-distractor effect: recall was higher at position 12 in the unchanging condition than in the changing condition. As predicted,
performance in the partially-changing condition fell between that of the other two conditions.

![Graph](image)

Figure 2: Mean number of words correctly recalled as a function of serial position and condition in Experiment 2.

Individual paired t-tests revealed that at the final serial position, none of the matched conditions (i.e., M-M-M and W-W-W; M-M-W and W-W-M; and M-W-W and W-M-M) differed from one another (all ts < 1). Therefore, conceptually similar conditions were collapsed for further analysis. At serial position 12, recall in the unchanging condition was reliably better than in the partially-changing condition ($F(1,28) = 4.21, MSe = .59, p < .05$) and recall in the partially-changing condition was reliably better than in the changing condition ($F(1,28) = 4.28, MSe = .40, p < .05$), as predicted by the CDP model.

A 3 conditions (unchanging, partially changing, or changing) by 2 distractor tasks (math task or word-pair task) by 12 serial positions ANOVA revealed only a main effect of serial position ($F(11,308) = 10.08, MSe = .54, p < .0001$). The main effects of condition and distractor task were not reliable, $F(2,56) = 1.39, MSe = .51, p > .20$, and $F(1,28) = 2.31$,
\(MSe = .88, p > .10,\) respectively. No interactions were reliable: for condition by distractor task, \(F(2,56) = 1.10, MSe = .55, p > .30;\) for distractor task by position, \(F(11,308) = 1.25, MSe = .45, p > .25;\) and for both the condition by position and the three-way interactions, \(F < 1.\)

Experiment 1 found that recall in the unchanging condition was higher than recall in the changing condition for the first half of the list, and Figure 2 suggests that there might be a similar pattern here. However, in neither half of the list was this difference reliable: for positions 1 through 6, \(F(2,56) < 1;\) and for positions 7 through 12, \(F(1,56) = 1.72, MSe = 0.45, p > .15.\) An unpredicted (by any theory) result from Experiment 1 was thus not replicated.

**Discussion**

Experiment 2 replicated the main Koppenaal and Glanzer (1990) finding that changing to a different distractor task at the beginning of the final distractor period eliminated or significantly reduced recency; moreover, it also confirmed the assumption of the CDP model that recall in a partially-changing condition would fall between the other two conditions. The reason is that the likelihood of an item’s being included in the set of plausible candidates is dependent upon the degree of similarity between the processing context of the item in question and the processing context of the other items: the processing context of the final item in the partially-changing condition bears more resemblance to that of the preceding items than does the processing context of the final item in the changing condition.

**EXPERIMENT 3**

It could be argued that the changing-distractor effect results from an exaggerated shift in attention from the to-be-remembered item to the novel distractor task, that the distractor tasks do indeed distract. Experiment 3 tested this idea by comparing three conditions, one where the distractor task never changed (unchanging); one where the task changed only after the final item (changing); and one where the distractor task changed after every item
(continually changing). If the attention hypothesis is correct, then the continually-changing condition should evidence a changing-distractor effect at every serial position, including the final one. That is, it predicts an equal reduction in performance at each serial position in the continually-changing condition compared to performance in the unchanging condition because every distractor task at every serial position is novel. If nothing else, the attention hypothesis predicts that recall at the final serial position in the continually-changing condition cannot be better than in the changing condition.

The CDP model predicts that overall, recall will be worse in the continually-changing condition but differs from the attention hypothesis by predicting better recall for the final item. If processing context is used to group the items, and if there is no consistent context, then fewer candidates will be selected during the coarse-search stage. But each item in the continually-changing condition will have an equal probability of being included in this pool. Once included in the pool, the most distinct item has the highest probability of being recalled. Conceptually, then, the continually-changing condition is more similar to the unchanging than to the changing condition and so should demonstrate a pattern of results more like the former than the latter.

Method

Subjects. Sixteen Yale University undergraduates served as subjects in exchange for credit in introductory psychology courses.

Design. There were three conditions, an unchanging condition where the nature of the distractor task remained constant throughout the list; a changing condition where the nature of the distractor task changed after the final item; and a continually-changing list where the distractor task changed after every item. The first two conditions resemble the unchanging and changing conditions in previous experiments.

Materials. All stimuli were presented on an Apple Macintosh Plus computer. There were five different distractor tasks, each of which lasted 6 seconds.

(1) Math: Subjects verified math problems and indicated whether the computer's
answer was true or false. First, the computer presented two integers simultaneously on the CRT, one number between 1 and 900 and the second between 1 and 4. At intervals of 800 ms, the computer then presented three more addends (between 1 and 4) and finally the sum of all of the above numbers. This sum was correct 50% of the time and incorrect by plus or minus 1 or 2 the rest of the time. The subjects had approximately 2800 ms to respond 'true' or 'false' by pressing a key on the keyboard.

(2) Count: In a small square (approximately 3 x 3 cm) in the center of the screen, the computer presented the digits 1 through 9, randomly selected, in 9 point Geneva typeface at a very fast pace (approximately 1 character every 76 ms). The subjects' task was to count, out loud, the number of 1s presented and, at the end of the task, to enter that number via the keyboard.

(3) Clicks: A Realistic 2.5" speaker was modified so that it produced almost no sound but merely vibrated or ‘clicked’ when a signal was sent via the serial port of the Macintosh to the speaker. The clicks could come in 2 different patterns, which occurred randomly and which the subjects ‘shadowed’ for 6 seconds by pressing one of two keys on the keyboard.

(4) Pictures: Three pairs of pictures were presented on the screen for 2 sec each. The pictures occupied an area of approximately 2.5 cm². The subjects' task was to verify the question, “The names of the objects represented begin with the same letter.” If, for example, pictures of a turtle and a train were shown, subjects were to respond ‘true’ because both begin with the letter ‘t’. If the pictures were of a turtle and an owl, they were to respond ‘false.’ They responded by pushing one of two keys on the keyboard.

(5) ABX: An ABX discrimination task used a seven item VOT continuum (from “gift” to “kift”). Voice-onset time is the time interval between the first release of air in pronouncing a consonant and the beginning of voicing, and is shorter for /g/ than for /k/. In a VOT continuum, each token differs from the other tokens in the duration of the VOT, which is lengthened as one moves from “gift” to “kift.” The stimuli were constructed by
digitizing the word "gift" on a computer, and then manually lengthening the VOT with a
digital sound editor. The task was constructed such that the A and B tokens were separated
on the continuum by at least three other tokens. The presentation of each of the tokens was
separated by 1666 ms SOA and the subject had 1500 ms in which to respond.

Each distractor task lasted 6 seconds and the use of each task was partially balanced
according to a Latin-square design; the design did not allow enough lists for a complete
counterbalancing scheme. Thus, there were 2 unchanging lists of each type of distractor
task, and in the changing condition the change from task to task was counterbalanced. In
the continually-changing condition, the location of each type of task was random. Each to-
be-remembered word was presented for 2 seconds, there were 5 words in each list, and each
subject received 30 lists, ten in each condition. The order of conditions was random, and 20
seconds were allowed for written free recall. All stimuli were presented on the CRT,
through two Tandberg 10 speakers powered by a Yamaha Ax 400U amplifier, or through
the modified Realistic speaker.

Procedure. Subjects were told that the experiment was investigating how flexible
people were in their ability to perform different tasks. Each task was described and
demonstrated using a HyperCard simulation and subjects practiced each task until they
could follow the instructions perfectly and felt comfortable with the task. Any remaining
questions were answered before the thirty experimental trials began. Subjects were tested
individually in a sound chamber and were allowed to adjust the CRT to a comfortable level
of brightness.

Results

As Figure 3 illustrates, the results are as predicted by the CDP model. Recall in the
changing condition is lower than in the unchanging condition at the final serial position,
replicating the basic changing-distractor effect. More importantly, overall recall is lower in
the continually-changing condition than in either of the other two conditions, but recall at the
final serial position is better than in the unchanging condition.
A 3 conditions (unchanging, changing, or continually changing) by 5 serial positions ANOVA supported the pattern of results apparent in Figure 3. There was a main effect of condition \( F(2,30) = 6.81, MSe = 3.11, p < .01 \), of position \( F(4,60) = 9.64, MSe = 3.83, p < .001 \), and a reliable interaction \( F(8,20) = 3.59, MSe = 1.34, p < .01 \). As predicted by the CDP model, there was reliably better recall of the final item in the unchanging compared to the changing condition \( F(1,15) = 7.74, MSe = 0.79, p < .05 \), and recall of the final item in the unchanging and continually-changing conditions was statistically indistinguishable \( F < 1 \). Contrary to predictions of the attention hypothesis, recall was actually better at the final serial position in the continually-changing condition than in changing condition \( F(1,15) = 5.46, MSe = 1.47, p < .05 \).

Discussion

If the surprise hypothesis were correct, performance at every serial position should suffer compared to the control condition because at each and every position a novel distractor task appears. Because it is the presumed novelty of the distractor task which
'grabs' attention away from the to-be-remembered item, there should not be any difference between recall of the final item in the continually-changing and changing conditions. Experiment 3 shows that this is clearly not the case; recall of the final item in the continually-changing condition is not different from recall in the unchanging condition and in fact is reliably better than in the changing condition.

The CDP model predicts and explains this result by assuming that while the continually-changing condition is at a disadvantage, overall, because there is no common context which serves to group the appropriate items, the final item is not as disadvantaged as in the changing condition because it is just as likely to be included in the pool of candidates as the other items in the list. The continually-changing condition is thus conceptually more similar to the unchanging than to the changing condition.

The type of explanation advanced by Koppenaal and Glanzer (1990) does not account for these results without modification. Their explanation states that the changing-distractor effect is due to the subjects’ being unable to continue a multi-tasking processing strategy when faced with a new distractor task. The continually-changing condition features a new distractor task after every item and so should prevent the strategy from developing. Without the ability to rehearse the final item, the subjects cannot prevent the subsequent distractor material from replacing the item in STS. While both the modal-model and the attention hypothesis can account for the lower recall in the continually-changing condition at positions 1 through 4, both explicitly predict worse performance at the final position than in the unchanging condition. Experiment 3 disconfirmed this prediction.

EXPERIMENT 4

Experiments 1 through 3 investigated the role of processing context in the changing-distractor effect and found that the CDP model of recall accounted for the results while explanations based on the modal model or on attention either could not predict the results or predicted opposite results. Nonetheless, the changing-distractor effect remains paradoxical because it demonstrates reliably worse recall of an apparently more distinctive item. There
is extensive documentation in the literature that altering an item in a list produces a von Restorff or isolation effect (see Wallace, 1965, for a review). For example, in her classic experiment, von Restorff (1933) presented subjects with lists composed entirely of CVCs with the exception of one item, a number (or vice versa). Recall of the different, or isolated, item was always greater than of a control item of the other kind. Common sense would seem to predict that performing a changing-distractor manipulation in the middle of the list might be functionally equivalent to an isolation manipulation. Experiment 4 tested this intuition by performing the changing-distractor manipulation at the first and third serial positions in the list as well as at the final position.

The CDP model predicts not only that the isolation effect will not occur (that recall at the targeted position will not be greater than in the control condition) but that a changing-distractor effect will occur (that recall at the targeted position will be lower than in the control condition). If the nature of the distractor task changes somewhere in a list, the item immediately preceding the change will be recalled less well than an appropriate control item. If the two-level model of recall assumed by the CDP model is correct, that is, if context and distinctiveness can be dissociated from each other, then the items preceding the change in distractor task should display worse recall. If the distinction between context and distinctiveness is not valid, then a von Restorff effect should be observed.

Additionally, Experiment 4 introduced more difficult distractor activities to counter the argument that the Koppenaal and Glanzer (1990) tasks were not sufficiently demanding to prevent covert verbal rehearsal. Rather than just adding 1 to a three-digit number or reading two words aloud, the subjects verified more complex math problems or performed a 5-item memory span task. These tasks were presented such that subjects’ responses were recorded and could be analyzed to determine if subjects were performing differently when the task was unique.

Method

Subjects. Twenty-nine Yale University undergraduates served as subjects in exchange
for credit in introductory psychology courses. An additional subject's data were discarded for not following instructions: he thought that he was supposed to wait until after the final list before attempting to recall any words.

Design. A completely within-subjects design examined four conditions. The unchanging condition featured a standard continual-distractor list where the nature of the distractor task remained constant throughout the entire list. The three other conditions manipulated where in the list the unique distractor task event would occur, either after the first item, after the third item, or after the final item. This latter changing condition served to ensure that the basic changing-distractor effect could be obtained in this particular setting.

Materials. All materials were presented on an Apple Macintosh Plus computer and the two distractor tasks were an addition task and a memory span task. For both the math task and the span task, the stimuli were presented by playing digitized numbers or letters to the subject over loudspeakers. In the math task, the computer read out five numbers (between 1 and 4) and then the sum of those numbers which was correct 50% of the time and incorrect by 1 or 2 the rest of the time. Subjects responded using the mouse to indicate whether the computer's answer was true or false. In the span task, five letters (randomly chosen without replacement from the pool c, g, h, k, m, q, r, t, and x) were read aloud by the computer, and the subjects had to recall them in serial order, again responding with the mouse. Both tasks lasted 8 seconds. The to-be-remembered words were presented for 1 second each, and the subjects read these words out loud. Each list contained 6 words, and each subject received 32 lists, 8 in each condition, with each condition occurring randomly once every 8 lists. Thus, there was great uncertainty, on the part of the subject, as to which task would occur when. Thirty seconds were allowed for written free recall. The stimuli were presented either on the CRT (words) or through two Tandberg 10 speakers powered by a Yamaha Ax 400U amplifier (distractor tasks).

Procedure. Subjects were told that the experiment investigated how well people could perform several tasks simultaneously. The addition and span tasks were then described and
demonstrated using a HyperCard simulation. Subjects were told that all three tasks were equally important, and that the occurrence of the math and span tasks would be randomly determined by the computer (which, of course, they were not). After any questions had been answered, the experiment began. Subjects were tested individually in a sound chamber and were allowed to adjust the CRT brightness and amplifier volume to comfortable levels.

Results

Figure 4: Mean number of words correctly recalled as a function of serial position and condition in Experiment 4. The same unchanging condition is replotted in each panel.
Experiment 4 demonstrated that the changing-distractor effect, as predicted by the CDP model, occurs not only at the final serial position, but throughout the entire list. Recall in the changing conditions was reliably lower than in the unchanging condition at each of the targeted serial positions: for changing after the first item, \( F(1,28) = 4.38, MSe = 0.79, p < .05 \); for changing after the third item, \( F(1,28) = 9.84, MSe = 0.69, p < .01 \); and for changing after the final item, \( F(1,28) = 7.04, MSe = 0.83, p < .05 \). The results suggest that context can operate differently from distinctiveness and, as Figure 4 illustrates, that one of the assumptions made by the CDP model is not without empirical support: a manipulation of context can reduce the likelihood of an item's being recalled when it decreases the similarity between the processing context of target item and that of the remaining items.

A 4 conditions (unchanging, changing after the first item, changing after the third item, or changing after the last item) by 2 distractor tasks (math or span) by 6 serial positions ANOVA confirmed the pattern of results evident in Figure 4. While there was a main effect of distractor task (\( F(1,28) = 8.84, MSe = 1.44, p < .01 \)), such that more words were recalled with the math distractor task than the span task, none of the interactions involving distractor task as a factor were reliable: for distractor by condition, \( F(3,84) = 1.17, MSe = 1.01, p > 0.30 \); for distractor by serial position, \( F(5,140) = 1.27, MSe = 0.93, p > .25 \); and for the three-way interaction, \( F < 1 \). The main effect of serial position was reliable (\( F(5,140) = 10.56, MSe = 1.91, p < .0001 \)), but that of condition was not (\( F(3,84) = 1.26, MSe = 0.89, p > .25 \)); the interaction between the two was reliable (\( F(15,420) = 1.98, MSe = 0.89, p < .05 \)).

When the distractor task changed after the first and third items, it also appeared to reduce recall of items surrounding the target position. When the change in distractor task occurred after the first item, recall of the second and third items in the changing condition was worse than in the unchanging condition, although only marginally (\( t(28) = 1.76, p < .10 \), and \( t(28) = 1.86, p < .10 \), respectively). When the change occurred after the third item, recall of the first and second items was not statistically lower in the changing condition than in the unchanging condition, both \( r < 1 \). When the change occurred after the final item,
there was no effect apparent at any position other than the targeted one.

The changing-distractor effect occurred despite the more demanding distractor tasks used. The subjects in Experiment 4 solved math problems with four addends and performed serial recall of a five-item list of letters presented at a rate of two items per second. Analysis of the distractor tasks revealed that subjects were accurately performing both tasks and were not merely guessing. On the unchanging lists, subjects answered an average of 2.97 out of 4 math problems correctly and recalled 14.0 out of 20 letters in the correct order. Moreover, subjects did not, with one exception, perform better when the distractor task was unique at positions 1, 3, or 6 compared to average performance on the task in the unchanging condition: for the math task $t(28) = 1.70, p > .10; t < 1; \text{and } t < 1$; and for the span task $t < 1; t(28) = 4.71, p < .01; t(28) = 1.66, p > .10$, respectively.

Discussion

Consistent with predictions of the CDP model, Experiment 4 demonstrated a changing-distractor effect at positions throughout the serial position curve. Processing context can serve as a basis of selecting a pool of candidates from which the final selection will be made and is not unique to the final position. When an item does not share the same processing context as the other target items, and it is the only item in the list that does not, the probability of recall of that item will be reduced. The modal model's explanation of the changing-distractor effect rests on the assumption that subjects develop a multi-tasking ability as the list progresses. It is hard to reconcile this assumption with the presence of a changing-distractor effect at the first serial position in the list, for in neither the changing nor the unchanging condition is anything different at that point as far as the subject is concerned.

Only once out of 6 comparisons did subjects perform better on the unique distractor

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3 The reason the maximum number of math problems correct is 4 is that while there were 8 lists in each of 4 conditions, there were only 4 lists of unchanging math, 4 lists of unchanging memory span, etc.
task compared to average performance in the control condition. Similar analyses were performed in Experiment 5 so detailed discussion of distractor task performance will be postponed until later. However, there is little evidence to support the idea that subjects process the unique distractor task differently, which might account for the reduced recall of the item preceding it.

It is of interest that changing the nature of the distractor task after the first item reduced recall of surrounding items while changing the task elsewhere did not. It is possible that when the change occurs after the first item in a list, recall of the second and third items suffers slightly because a perceptual anchor has been removed (e.g., Glanzer & Dolinsky, 1965). Koffka (1935, p. 450) expressed the same idea, albeit somewhat differently: as more items are included in a set, the range of what will be accepted as a new member decreases:

If each member of a temporal unit depends upon the field produced by the preceding members as well as upon its own stimulus, then we can also understand why the direction of the unit becomes more and more determined the further the sequence proceeds. With each new member the field grows in extent and thereby in power.

In an important footnote to this statement, he added that "Not only does the field become gradually organized, it may also become re-organized." Thus, it is possible to have 'false starts' in a set, where the first item does not fit with later items. This is precisely the case when the distractor task changes after the first item, and to a lesser extent when the change occurs after the third item: the organization of the list is disrupted.

The fact that changing the distractor task sometimes caused items adjacent to the target item to be recalled less well, that is exhibited a 'spread of effect', serves only to underscore the main finding of Experiment 4: the changing-distractor effect is observable at all serial positions and behaves fundamentally differently from effects due to manipulations of distinctiveness.
EXPERIMENT 5

Experiment 4 demonstrated that the changing-distractor effect is different from the isolation effect, that manipulations of processing context produce different results than do manipulations of distinctiveness. Experiment 5 tested the assumption of the CDP model that context manipulations produce different results than do distinctiveness manipulations because they operate at different stages in the recall process, that the changing-distractor effect is a pre-selection effect (i.e., occurs during the first stage of the recall process), while the von Restorff effect is a post-selection effect (occurs during the second stage). For example, while Experiment 1 demonstrated the changing-distractor effect with incidental learning, the vast majority of studies on the von Restorff effect have failed to show an effect with incidental learning (e.g., Postman & Phillips, 1954; Wallace, 1965).

Experiment 5 examined the relation between the changing-distractor effect and the isolation effect. There were four conditions arising from crossing unchanging and changing-distractor lists with a normal or isolated target item; in addition the manipulations were made at two different serial positions. If the effects of context and distinctiveness are independent, then one should observe (1) a changing-distractor effect regardless of whether the target item is isolated and (2) a von Restorff effect regardless of whether the target item is in an unchanging or changing list. The CDP model predicts, then, that the two manipulations will not interact.

Method

Subjects. Thirty-two Yale University undergraduates served as subjects in exchange for credit in introductory psychology courses. Subjects were assigned to one of two groups based on the order of arrival in the laboratory.

Design. The unchanging condition was a standard continual-distractor list where the nature of the distractor task remained constant throughout the list. In the changing condition, the nature of the distractor task changed after the target item. The other two conditions were identical to these unchanging and changing conditions except that the target
item was isolated to induce a von Restorff effect. Isolation was achieved by increasing the size of the font from 14 point Times (in the normal conditions) to 24 point Times (in the isolated conditions). The sole difference between the groups was that in one the manipulations occurred at the third serial position while in the other the manipulations were made at the final serial position.

Materials and Procedure. All materials were presented on an Apple Macintosh SE computer. The materials and procedure were the same as in Experiment 4, except that auditory stimuli were presented over Signet TK22 headphones powered by a Realistic QA-620 amplifier. Subjects were tested individually in a sound chamber and were permitted to adjust both the brightness of the CRT and the output of the amplifier to comfortable levels.

Results

Experiment 5 demonstrated a changing-distractor effect and a von Restorff effect at both the third and the final serial positions. Moreover, as Figure 5 suggests, there was no apparent interaction at either of the test positions.

![Figure 5: Mean number of words correctly recalled as a function of condition and serial position from Experiment 5. The left panel displays the results when the manipulation occurred at the third serial position and the right panel when the manipulation occurred at the final serial position. Note that the panels have different scales.](image-url)
Primary Analyses. A 2 groups (position 3 or position 6) by 2 conditions (unchanging or changing) by 2 isolations (normal or isolated) by 2 distractor tasks (span or math) ANOVA on recall at the targeted serial positions revealed the predicted main effects of condition ($F(1,30) = 20.56, MSe = .80, p < .0001$) and isolation ($F(1,30) = 28.04, MSe = .87, p < .0001$) and no interaction between the two ($F(1,30) = 0.01, MSe = .47, p > .90$).

Because a null effect was predicted, a power analysis was performed on the interaction. The procedure recommended by Cohen (1988) determined that the effect size of the interaction was negligible; in other words, approximately 2000 subjects would be needed to detect an effect one-half the size of Cohen's smallest effect size. In contrast, the experiment had power levels of .83 and .94 to detect the respective main effects. If there is a nontrivial effect in the interaction, the number of subjects required to reliably detect it renders it theoretically unimportant.

The ANOVA also revealed a main effect of position ($F(1,30) = 28.11, MSe = 2.61, p < .0001$), indicating better recall at position 6 than at position 3 (a recency effect), but the main effect of distractor task was not reliable ($F(1,30) = 2.40, MSe = .86, p > .10$). None of the interactions were reliable; all had $Fs < 1$ except for the position by distractor task interaction, $F(1,30) = 2.00, MSe = .86, p > .10$, and the four-way interaction, $F(1,30) = 1.60, MSe = .88, p > .20$.

Continuing the analysis at the two targeted positions, there were reliable effects of isolation and of changing the distractor task as predicted. For position 3, recall was reliably better in the unchanging condition than in the changing condition ($F(1,15) = 10.65, MSe = .85, p < .01$), and recall was reliably better in the isolated condition than in the normal condition ($F(1,15) = 24.27 MSe = .68, p < .001$). Moreover, recall in the unchanging isolated condition was higher at position 3 than either the unchanging normal condition ($F(1,15) = 14.61, MSe = .57, p < .01$) or the changing isolated condition ($F(1,15) = 5.54, MSe = .82, p < .05$), while that of the changing normal condition was lower at position 3 than either the unchanging normal condition ($F(1,15) = 6.03, MSe = .75, p < .05$) or the
changing isolated condition \((F(1, 15) = 9.93, MSe = .83, p < .01)\).

For position 6 the pattern was almost identical. Recall was reliably better in the unchanging condition than in the changing condition \((F(1, 15) = 9.91, MSe = .76, p < .01)\), and recall was reliably better in the isolated condition than in the normal condition \((F(1, 15) = 8.04, MSe = 1.06, p < .05)\). Moreover, recall in the unchanging isolated condition was higher at position 6 than in either the unchanging normal condition \((F(1, 15) = 6.32, MSe = .63, p < .05)\) or the changing isolated condition \((F(1, 15) = 8.46, MSe = .42, p < .05)\), while performance in the changing normal condition was lower at position 6 than in either the unchanging normal condition \((F(1, 15) = 7.06, MSe = .57, p < .05)\) or the changing isolated condition \((F(1, 15) = 6.96, MSe = .65, p < .05)\).

A 2 groups (position 3 or position 6 manipulated) by 2 conditions (unchanging or changing) by 2 isolations (normal or isolated) by 2 distractor tasks (span or math) by 6 serial position ANOVA revealed a reliable main effect of condition \((F(1, 30) = 7.66, MSe = .92, p < .01)\), of distractor task \((F(1, 30) = 6.95, MSe = 1.05, p < .05)\), and of serial position \((F(5, 150) = 31.75, MSe = 1.94, p < .0001)\). The main effects of group \((F(1, 30) = 1.39, MSe = 10.54, p > .20)\) and isolation \((F < 1)\) were not reliable. More words were recalled in the unchanging than in the changing conditions, and more words were recalled when the distractor task was the span task than when it was the math task. Of theoretical importance, there is again no reliable interaction between condition and isolation \((F(1, 30) = 0.01, MSe = .84, p > .90)\).

There were only two interactions involving distractor task which were reliable: the condition by distractor task interaction \((F(1, 30) = 7.34, MSe = .66, p < .05)\) and the condition by distractor task by position interaction \((F(5, 150) = 2.65, MSe = .90, p < .05)\). The first reflects the observation that while words were better recalled in the unchanging than changing conditions and with the span task than with the math task, the combination of the math task with the changing condition was particularly damaging. The second interaction would have been problematical if it had involved either position 3 or position 6,
but further analyses did not indicate this.

The group by condition by position interaction \( (F(5,150) = 6.31, MSe = .64, p < .001) \)
and the group by isolation by position interaction \( (F(5,150) = 3.19, MSe = .84, p < .01) \)
arose from the nature of the design, as did the isolation by position interaction \( (F(5,150) = 4.92, MSe = .84, p < .01) \). None of the remaining interactions were reliable and all had \( F \)s < 1 except: group by isolation \( (F(1,30) = 2.36, MSe = 1.20, p > .10) \); group by distractor task \( (F(1,30) = 1.20, MSe = 1.05, p > .25) \); group by position \( (F(5,150) = 1.61, MSe = 1.94, p > .15) \); condition by position \( (F(5,150) = 1.22, MSe = .64, p > .30) \); group by condition by isolation by position \( (F(5,150) = 1.14, MSe = .80, p > .30) \); and condition by isolation by distractor task by position \( (F(5,150) = 1.39, MSe = .71, p > .20) \).

Unlike all other experiments, there was some evidence of a reliable spread of effect for the positions adjacent to the manipulation. Analyzing differences at position 5 when the manipulation occurred at the final serial position, there were reliable differences between recall in the unchanging normal and unchanging isolated conditions, \( t(15) = 2.84, p < .05 \); between the unchanging normal and changing normal conditions, \( t(15) = 3.59, p < .01 \); and between the unchanging normal and changing isolated conditions, \( t(15) = 4.48, p < .001 \). There was a marginally reliable difference between recall in the unchanging isolated and changing isolated conditions, \( t(15) = 1.81, p < .10 \), but none of the remaining differences were reliable (all ts < 1). For serial position 4, there were marginally reliable differences between recall in the unchanging normal and unchanging isolated conditions \( (t(15) = 1.96, p < .10) \) and the unchanging isolated and changing normal conditions \( (t(15) = 2.11, p < .10) \). The remaining differences were not reliable (all ts < 1).

Analyzing differences at position 2 when the manipulation occurred at the third serial position, the largest difference, that between recall in the unchanging normal and the changing normal conditions, was only marginally reliable, \( t(15) = 1.80, p < .10 \). For all other comparisons at that position, \( t < 1 \). At position 4, the largest difference was between recall in the unchanging isolated and changing isolated conditions and was not reliable, \( t(15) \).
As in Experiment 4, there was some, but not much, spread of effect. Analysis of the distractor tasks revealed that subjects receiving the manipulation at position 3 performed accurately, getting 3.21 out of 4 math problems correct and 15.5 out of 20 letters recalled in the correct order on the span task. Subjects did not perform better when the distractor task followed an isolated item, when the distractor task was unique, or when both occurred, compared to average performance on the task in the control condition: for the math task $t(15) = 1.47, p > .10$; and for the span task $t(15) = 1.40, p > .10$; $t(15) = 1.69, p > .10$; $t(15) = 1.24, p > .10$, respectively.

Subjects receiving the manipulation at position 6 performed statistically indistinguishably from their counterparts, getting 3.26 out of 4 math problems correct and recalling 16.4 out of 20 letters in the correct order on the span task. They did not perform better when the distractor task followed an isolated item, was unique, or when both occurred, compared to average performance on the task: for the math task $t < 1$; $t < 1$; and for the span task $t(15) = 1.44, p > .10$; $t(15) = 1.49, p > .10$; and for the span task $t < 1$; $t < 1$; $t < 1$, respectively. Experiment 5 found no evidence that subjects were performing differentially on the distractor tasks, either between groups or across conditions.

Discussion

The observed independence of the changing-distractor and isolation effects found in Experiment 5 supports the assumption that these effects occur at different stages in the recall process. Moreover, it demonstrates that the concepts of context and distinctiveness can be experimentally dissociated. If an item is isolated, it does not matter if the distractor task remains unchanged or changes after the item: recall of that item will be better than in the appropriate control condition. Similarly, if the nature of the distractor task changes in a list, it does not matter whether the item preceding the change is isolated or not: recall will be lower than in the appropriate unchanging list.

For 6 out of 6 comparisons, subjects performed statistically indistinguishably on the unique distractor task and on the task following the isolated item compared to average
performance in the control condition. As in Experiment 4, there is little evidence to support the idea that differential attention to the distractor task leads to the changing-distractor effect. This is consistent with the finding of Einstein, Pellegrino, Mondani, and Battig (1974) that the isolated item in a typical isolation experiment receives no more rehearsal than control items. Neither the changing-distractor effect nor the von Restorff effect appears to be due to differential rehearsal.

GENERAL DISCUSSION

While it is possible to explain the outcomes of the five experiments reported here piecemeal using different constructs, assumptions, and provisos for each, the CDP model predicts and explains, without modification, the results of all five experiments. When faced with recall of a list, and when other recall cues are of little use because rehearsal and other mnemonic strategies have been curtailed, subjects employ a two-stage recall process. In the first stage, a coarse search separates plausible candidates from implausible ones. One method of doing this is according to some knowledge of how the target items were processed: to the extent that an item shared a processing context similar to the target context, it is more likely to be included in the pool. After the pool has been generated, final selection is made according to other principles, such as distinctiveness. The more distinctive in some fashion the item is from the other candidates, the greater the probability that it will be recalled.

Experiment 1 found that intentional learning was not a necessary precondition for obtaining a changing-distractor effect. The CDP model predicted this because it assumes that people use processing context to generate candidates at the time of recall, not during list acquisition. The results from Experiment 2 were predicted by the assumption that the likelihood of an item's being included in the set of plausible candidates is dependent upon the degree of similarity between the processing context of the item in question and the processing context of the other items. In Experiment 3, three different conditions were tested. Superficially, the continually-changing condition appeared more similar to the
changing than to the unchanging condition. However, the CDP model views the continually-changing condition as more similar to the unchanging condition because in both conditions, each item in the list is equally likely to be included in the pool of candidates. Thus, the CDP model predicted the difference in recall between the changing and the continually-changing conditions. Experiment 4 demonstrated both the generality of the changing-distractor effect and that the changing-distractor effect is different from the isolation effect; manipulations of processing context produce different results than do manipulations of distinctiveness. Experiment 5 provided evidence consistent with the assumption that the coarse and detailed stages are independent, such that context and distinctiveness operate at different stages of the recall process. Finally, in addition to predicting the results in the five experiments, the CDP model also predicts that in general, effects found in so-called short-term memory experiments can be found in long-term memory settings, as well as the reverse (Crowder & Neath, 1991). The changing-distractor task is just as evident in 5-item lists as in 12-item lists.

The first of three possible alternate explanations is derived from the modal model. This view assumes that subjects develop a time-sharing process whereby rehearsal of the to-be-remembered items occurs while the distracting material is being processed. In this way, a recency effect can be observed in the continual-distractor paradigm: the distracting activity does not remove items from STS because the subjects have learned to rehearse and maintain them while still processing the distractor tasks. However, because the strategy develops over the course of a list, it cannot explain a changing-distractor effect at the first serial position of a list, and, because the strategy is developed to help recall, it cannot be invoked when an incidental learning procedure is used.

A second possibility, similar to the first, is that the distractor tasks draw differential amounts of processing power away from rehearsal of the to-be-remembered item. That is, subjects do not process the common and novel distractor tasks equally. However, there are two lines of evidence against this view. First, the changing-distractor effect was observed
with incidental learning when there was no reason for the subjects to be rehearsing. Second, Experiments 4 and 5 did not find any replicable differences in subjects' performance on the distractor tasks when the task was unique versus when it occurred throughout the list.

A third possibility assumes that the novel distractor task draws attention away from the to-be-remembered item, resulting in reduced performance. The idea is that while not necessarily disrupting rehearsal, the surprise of a novel task reduces the salience of the preceding event. While this explains the changing-distractor effect at the final serial position and under incidental learning conditions, it cannot explain the results of Experiments 3 and 4. In the continually-changing condition, the distractor task is always novel, and thus, according to the attention hypothesis, one should observe a changing-distractor effect at each serial position; however, recall at the final position was better in the continually-changing condition than in the changing condition. In Experiment 4, a changing-distractor effect occurred when the change occurred after the first serial position when there was presumably no difference between the conditions as far as the subject is concerned.

Of the above models, the CDP model provides the better explanation of the data, yet there are aspects left unaddressed. For example, the changing-distractor effect is not surgical in its precision: in Experiment 4 when the task changed after the first serial position, recall suffered in the changing condition at the following two serial positions. This result was easily explained post hoc, as noted in the discussion of that experiment, but in Experiment 5 there were reliable differences at serial positions adjacent to the point where the manipulation was made. This finding is reminiscent of the 'spread of effect' sometimes observed with the von Restorff effect, and sometimes not. In his review, Wallace (1965) found that some researchers reported a positive effect on recall at adjacent positions when an isolation manipulation was made, some reported a negative effect, and still others reported no effect. No tenable explanation has been offered in the literature, and none can be garnered from the experiments reported here. However, the spread of effect due to
changing the distractor task does appear to be exacerbated by the isolation manipulation. The only reliable spread of effect in the first four experiments appeared when the change in distractor tasks was made after the first serial position; in the final experiment, which had an isolation manipulation, a reliable spread was observed.

It should be remembered that regardless of the particular experimental manipulations, items in a list form associations with and affect the processing of the other items. It should not be surprising, therefore, that a manipulation at one position can affect other adjacent positions. This serves to emphasize a point made by the current CDP model: items within a list do not exist 'in a vacuum': they affect, and are affected by, the context in which they are processed and the other items in the list contribute to defining the context.

Episodic and Semantic Memory

The CDP theory suggests a way of conceptualizing the differences found between episodic and semantic memory without postulating different systems (see Tulving, 1983). Rather than a dichotomy, the CDP view sees episodic and semantic memory as endpoints on a continuum of how well the originating processing of the item has been ingrained. For example, the months of the year have been processed so often and are so well known that one can hardly fail reinstate the process. Or perhaps there are so many different 'original' processes that reinstating one becomes trivial.4 The same is true of the alphabet; for the multiplication tables, this may be less true, and for the presidents of the United States, even less so.

If episodic and semantic memory are points on a continuum and there is no

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4 Endel Tulving (1983) provides a nice illustration of this point with an informal experiment in which people were required to recall the months in alphabetical order. Chances are, this way of ordering the months has rarely been done by most people. His subjects were uniformly worse recalling in this order than in chronological order. With practice, one would assume the process of alphabetical ordering to become as fluent as chronological ordering. According to CDP, what happens is that the processing becomes easier to reinstate with practice.
fundamental, qualitative difference between them, then a recency effect should be observed for items in semantic memory. Roediger and Crowder (1976) found just such a recency effect when they asked students to recall the presidents of the United States. The CDP model, with its two-stage recall process, predicts and explains this finding: in the first stage, all possible people who were presidents are formed into a group of candidates based on how they were originally processed. For example, Washington, as the first president, is processed almost continually (for Americans at least) and so there is a greater chance of the associated processing to be easily reinstated. Presidents such as Tyler, Fillmore, and Polk, presumably, have been processed less. Others such as MacArthur or Kissinger may have been processed in the context of the White House without ever actually being elected may still be included in the pool of candidates. During the second stage, the most distinctive candidates are actually recalled. As reflected in data collected in a replication, the most recent presidents (in addition to Washington, Jefferson, and Lincoln) were recalled best, presumably because their processing was more easily reinstated, but MacArthur was recalled more often that Polk, presumably because the general was more distinct.

The question then arises, “Are there any memories which are everlasting or permanently impressed, as for example, those seemingly recalled after a lapse of many years?” The CDP view, in agreement with Wechsler (1962, p. 151), who posed this question, answers “Generally no. Contrary to common opinion nearly everything that is acquired or learned is eventually obliterated, usually in a very short time.” As multiplication tables are remembered less well when continual drilling ceases after junior-high school, so too do other events become more vague with disuse. The reason, suggested by the CDP view, is that the processes associated with how the information was acquired cannot always flawlessly be reinstated, and if the processes are not rehearsed sufficiently often, the processes may be lost completely.

Generality

The importance placed on continual rehearsal to maintain recallability of items raises
questions about the use of the continual-distractor paradigm. This paradigm is designed to control rehearsal and to minimize the chance that subjects are developing special, idiosyncratic strategies; to the extent that the distractor tasks fully occupy the subjects' attention between items, memorizing will take place only when the item is presented. The question naturally arises as to whether this constraint produces results typical only of the laboratory, events which are different or even irrelevant in everyday life. The naturalistic studies by Baddeley and Hitch (1977) and Pinto and Baddeley (1986) argue strongly against this. These two studies required people to recall a list of events also separated by irrelevant, possibly distracting material. Conceptually, these experiments are identical to the laboratory versions and, moreover, the results are also similar. The other advantage of the continual-distractor paradigm is that to the extent that mnemonic strategies are reduced, the results will reveal the properties of the memory system itself.

Estes (1985) has suggested a possible method of conceptualizing rehearsal which fits in well with the CDP framework. Rehearsal may lead to multiple memory representations of temporal and contextual information for a given item, because each rehearsal can be seen as a re-presentation of the item. In terms of the CDP model, rehearsal serves to increase the range of processes with which the rehearsed item is similar, increasing the probability that it will be included in the pool of candidates. This view permits rehearsal to include nonverbal rehearsal (e.g., Watkins, Peynircioglu, & Brems, 1984).

Because the CDP view of memory does not require any verbal processes, it is readily applicable to animals other than humans. Pigeons, apes, and other species demonstrate recency as well as other serial position effects (e.g., Hitch, 1984, 1985; Wright et al., 1985), and the same explanation can be given for these findings as well as for those from human subjects. The classic generate-recognize models relied on a semantically arranged network of nodes representing words and the modal model does not easily accommodate nonverbal stimuli. The CDP view requires only that an animal be capable of reinstating past experiences, a requirement first suggested by Aristotle (Burnham, 1888).
Levels of Processing

The CDP model is by no means the only alternative to the modal model. Craik and Lockhart (1972) proposed a framework based on the idea of levels of processing (LOP): the 'deeper' the processing, the better the recall. As does the CDP model, the LOP view avoids the storage metaphor of memory and emphasizes processing. The main weakness of LOP is its apparent circularity: items are recalled best when deeply processed and evidence for deep processing occurs when items are well remembered (e.g., Baddeley, 1978). CDP offers a principled reason for the assumption that deeper processing leads to better memory and also provides a way of avoids the circularity of the original levels formulation.

An example of shallow processing might be attending only to the initial letter of the word; an example of deep processing might be fully exploring all the semantic relations of the word. In a typical experiment, memory for the words, as measured by a free recall test, would be better under the second condition than under the first. The reason, according to the CDP model, is that deeper processing is actually multiple processing: not only is the meaning of the word itself processed, but also its relation to other words. The more processes performed on an item, the greater the probability of being able to reinstate one when performing the coarse search. If only one process were performed, a failure to reinstate would necessarily mean a failure to recall; if many processes were performed, a failure to reinstate one process would not necessarily result in a failure to recall. The advantages of the LOP view can be incorporated into the CDP model, and the disadvantages (i.e., circularity) can be avoided with the principled explanation for what is deep and what is narrow.

A skeptical reader might ask whether the CDP model merely substitutes 'number' for 'levels'. The answer turns out to rest on an empirical test. An experiment can be constructed which manipulates the number of different processes to be performed on the word. The experiment could be constructed such that time of processing is disentangled from number of processes performed, and other similar confounds are controlled for. The
CDP model makes the clear prediction that the greater the number of processes performed, the greater the probability of recall. If this does not turn out to be the case, then this aspect of the CDP model is clearly incorrect.

An Embarrassment of Riches?

The above considerations address a final question about whether the CDP theory is too successful, if it possess an embarrassment of riches. Can it, in principle, be falsified? Any one of the experiments reported here could have had a different outcome, one not predicted by CDP. It did have to be the case, for example, that the isolation effect and changing-distractor effect operate independently, or that the changing-distractor effect occurred at every serial position.

The theory also makes several predictions which may or may not be found empirically. First, the CDP model assumes that the stimuli do not have to be verbal; in fact, it predicts that the same effects will obtain with nonverbal stimuli such as pictures. A clear demonstration to the contrary would severely limit the scope of the theory. Second, the model predicts that some animals should show the same pattern of results; again, this might not be the case. Third, as noted above, it specifies how episodic and semantic memory differ and the process whereby the former becomes the latter. It is possible that experiments can demonstrate that this formulation is incorrect. Fourth, as discussed above, its speculations about levels of processing can also, in principle, be contradicted by empirical results.

Another consideration is that the CDP model is by no means complete and is not intended as a mode capable of explaining any and all phenomena; for example, it does not address modality differences and can give no explanation for the spread of effect in Experiment 5. The benefit of the model, it seems, is in providing a new general framework: the modal model has officially ceased to be (e.g., Crowder, 1982), but there is no replacement that is general enough to apply widely yet simple enough to be falsifiable (e.g., Gardiner, 1983). The few principles suggested and assumptions made by the CDP model
have already been investigated to some extent, and so far the results seem favorable. Although the roles of many factors are still unknown and many assumptions are as yet untested, perhaps the most important contribution of the COP model of memory is that it may provide a way of viewing memory which could lead to new discoveries, new insights, and a new understanding of how beings remember.

CONCLUSION

The five experiments reported here provide evidence supporting the CDP model of memory. The theory assumes that when people recall a list of items, they first assemble a pool of candidates based on knowledge of what the target items should be like. One method of doing this is to reinstate the processes used when the items were originally experienced. According to the CDP model, the act of remembering consists of reactivating the neural mechanisms used to originally process the stimulus. To the extent that the reactivation reinstates the appropriate neural states present at the time of original processing, the item will be accurately re-experienced or remembered. During the second stage, which is independent of the first, the pool of candidates is examined in a more detailed search to determine final selection. At this point, the more distinctive the item, the greater the probability of selection.
REFERENCES


