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Endogenous versus exogenous attentional cuing effects on memory

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Abstract

Three experiments were conducted to investigate the influence of early attentional cuing effects on subsequent memory. In an incidental study phase, a cue preceded two simultaneously displayed words. An endogenous cue (row of arrows pointing toward one word) or an exogenous cue (row of stars at the location of one word) indicated which word to read aloud. In a subsequent test phase, memory for these cued and uncued words was measured. In Experiment 1, these attentional manipulations had almost no effect on subsequent implicit memory measured using a speeded reading (naming) test. Experiments 2 and 3 demonstrated that, on an explicit memory test, words were reliably better recognized in the endogenous condition than in the exogenous condition. These results suggest that endogenous attentional cues promote more active processing and hence elaboration of words, assisting their subsequent conscious retrieval.

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1. Introduction

Attention and memory have often been treated as quite separate domains. Attention has been seen as "low level" cognition, grouped with perception. Memory has been seen as more "high level" cognition, grouped with learning. Yet attention and memory must interact often and intimately. There has been increasing interest in studying their relation (e.g., MacDonald & MacLeod, 1998; Mulligan, 1997, 1998, 2003; Szymanski & MacLeod, 1996). This research has been primarily concerned with how later memory is influenced by earlier attentional manipulations, viewing attention as a "gatekeeper" for memory. A common finding of these studies is that attentional manipulations influence explicit and implicit memory differently.

The implicit/explicit distinction (Graf & Schacter, 1985) has dominated memory research for a quarter century. Explicit memory refers to the conscious recollection of previously experienced information and is tested with direct memory tests—usually recall and recognition—on which a conscious connection is made between an earlier learning episode and the present test situation. The participants know that they are remembering knowledge acquired earlier. Implicit memory, on the other hand, refers to the unconscious use of memory and is tested with indirect memory tests in which the participants are not aware of using knowledge from a prior learning episode. Implicit memory tests can be either conceptual, such as the category-exemplar production task (e.g., Mulligan, 2002; Mulligan & Stone, 1999), or perceptual, such as the perceptual identification task (Jacoby, 1983; Masson & MacLeod, 1992) and the speeded reading test (e.g., MacLeod & Masson, 2000). Usually, performance on these indirect tests is facilitated by memory, with participants being faster or more accurate for previously presented information. This enhancement due to memory is called priming or repetition priming.

Szymanski and MacLeod (1996) investigated the impact of attention during encoding on later retrieval, contrasting implicit and explicit memory tests. Using a modified Stroop task, they tested the hypothesis that attention during encoding is necessary for explicitly but not for implicitly tested memory. During study, the participants were asked either to read words aloud, ignoring their printed color, or to name the colors of the words aloud, ignoring the words themselves. Explicit recognition of the studied words was worse when participants had named the colors than when they had read the words. In contrast, in the implicit condition, there was no reliable difference on the lexical decision task between the two study conditions. Put simply, the attentional manipulation during study strongly affected explicitly tested memory but had no effect on implicitly tested memory.

MacDonald and MacLeod (1998) pursued this issue, investigating the sensitivity of explicit and implicit memory tests to reductions of attention during encoding. In their first two experiments, a single word was shown in red or in white on each trial. The participants read red words aloud but white words silently. On a subsequent explicit recognition test, memory was much better for the words read aloud than for those read silently. On a later implicit speeded reading test, however, memory for the two types of studied words was equally good, both showing substantial priming. Consistent with the findings of Szymanski and MacLeod (1996), then, attention seemed crucial for explicit but not for implicit memory testing.

In their third experiment, however, MacDonald and MacLeod (1998) implemented a more severe attentional manipulation. On each trial, two words—one red and one white—were presented simultaneously. The participants still had to say the red words aloud while ignoring the white words. Now, both the implicit and the explicit tests were affected: On both tests, memory for the words read aloud was significantly better than for those read silently. These results suggest that a certain minimal amount of attention is needed for memory, even on an implicit test. When presented alone, a white word could not be ignored; when presented with a red word, a white word could be ignored.

Mulligan (1997) also varied the amount of attention during encoding, in his case by manipulating attentional load. During study, the participants first saw a string of three to five random digits, then the target word, and then had to recall the string of digits. Memory was then explicitly tested on a category cued recall test or implicitly tested on a category-exemplar production test. Again, both implicit and explicit memory tests were influenced by attentional load, but implicit memory was only influenced by the higher attentional load, whereas explicit memory was influenced regardless of load. This is consistent with the idea that explicit memory is more affected than is implicit memory by attentional manipulations during encoding, dovetailing nicely with the results of MacDonald and MacLeod (1998) and Szymanski and MacLeod (1996).

Studies by Stone, Ladd, Vaidya, and Gabrieli (1998) and Rajaram, Srinivas, and Travers (2001) provided supporting evidence. Both used color-naming tasks as in Szymanski and MacLeod (1996) and both showed that some attention was required for priming on perceptual implicit tests, but probably less than that required for successful remembering on explicit tests. Stone et al. used the masked word identification implicit test and Rajaram et al. used the word stem and fragment completion implicit tests, so there is by now considerable generalizability for this conclusion.[2]

All in all, attentional manipulations do appear to influence both explicit and implicit memory. It is also apparent that explicit memory tests are more affected by these manipulations than are implicit memory tests. Explicit memory tests are more sensitive to changes in attentional load and selective attention during encoding, whereas implicit memory tests are less affected by such relatively subtle manipulations.

The results of these studies are consistent with the transfer-appropriate processing framework (Morris, Bransford, & Franks, 1977). This view proposes that memory is best when there is a good match between how items are studied and how they are remembered at the time of test. Although all four combinations do exist, explicit memory tests are mostly concerned with semantic/conceptual processing, whereas implicit memory tests concentrate more on perceptual features of the to-be-learned items (Roediger, 1990). Therefore, the transfer-appropriate processing perspective would anticipate different effects of early attentional manipulations on typical explicit versus implicit tests.

For conceptual processing, conscious attention is necessary during encoding to support successful recall or recognition during the test phase. Therefore, attentional manipulations should influence explicitly tested memory. On the other hand, perceptual processing as measured by typical perceptual implicit tests requires less conscious attention during encoding, so attentional manipulations should affect these implicit tests less. The studies just discussed do in fact demonstrate that explicit tests are more sensitive than implicit tests

[2] This conclusion can be further refined: Perceptual and conceptual implicit memory tests appear to be differentially affected by divided attention manipulations. Whereas perceptual implicit tests can be affected by but are relatively insensitive to divided attention manipulations (e.g., Mulligan, 2003; Mulligan & Hornstein, 2000; Szymanski & MacLeod, 1996), conceptual implicit tests tend to be more sensitive and more consistently affected (Mulligan, 2003; Mulligan & Hartman, 1996).

to attentional manipulations during encoding. Even perceptually driven explicit tasks are affected by divided attention manipulations (Mulligan, 1998).

The goal of the current research was to further investigate this complex relation between attention and memory. This time, emphasis was on endogenous versus exogenous attentional cuing, a familiar manipulation in the attention literature (e.g., McCormick, 1997; Stolz, 1996; Theeuwes, 1991; Yantis & Jonides, 1984). In the field of visual and spatial attention, attention can be cued in two distinct ways (see Theeuwes, 1994; Yantis, 1993). An endogenous cue is directional and the response to it is voluntary. Prototypically arrows, endogenous cues can be seen as activating top-down processes and as involving conscious control. In contrast, an exogenous cue (e.g., movement, color, sudden onset or offset) is stimulus-driven and involuntarily captures attention. Exogenous cues can be seen as activating bottom-up processes and as more automatic, not requiring conscious control.

This endogenous–exogenous distinction is particularly relevant to the relation between attention and memory because information studied in memory experiments is usually visually attended (e.g., words and pictures). Therefore, first contact with information to be learned and remembered is either by directing (endogenous) or by attracting (exogenous) attention. So, consideration of an endogenous–exogenous attentional cuing manipulation is a worthwhile step in investigating the relation between attention and memory.

We addressed the following key question: What is the influence of endogenously versus exogenously cued attention during a study phase on later implicit versus explicit memory? This question is important because previous studies about divided attention have demonstrated that attentional manipulations do have considerable influence on later memory (e.g., Mulligan, 1998, 2003; Mulligan & Hornstein, 2000), with explicit memory being more sensitive than (perceptual) implicit memory. Would the same pattern of results occur using a manipulation of attention that takes place earlier in the stream of processing? Indeed, how early do attentional processes exert their effect on memory?

We conducted three experiments, all involving an incidental study phase and then a test phase. In the study phase, two words were presented on a computer screen, with one of them cued either endogenously or exogenously. The participants had to say the cued word aloud, ensuring registration and word identification. After the study phase, the participant's memory was unexpectedly tested for both the cued and uncued words. Our interest was in how well participants would remember these words as a function of the type of cue and the type of memory test.

One possibility, of course, is that these types of cues are too early in the stream of processing to affect memory at all. Attentional effects on memory typically contrast a condition involving distraction to one not involving distraction during encoding. When the words are ignored, as when they must be color named, or when attention is divided between the primary word encoding task and a secondary task, memory performance is poorer than when there is full attention to the words. Coming during encoding, this kind of attentional manipulation is certainly more intrusive than a manipulation prior to encoding, such as the cuing manipulation examined here. So the first question is whether cues that signal what to process can have any influence at all on that processing.

The attentional cues to be examined here differ primarily in whether they are more automatic—exogenous cues—or more controlled—endogenous cues. Endogenous cues should require more active processing. In the memory literature, it is well established that incrementing active processing improves memory. Perhaps the best illustration of this is the generation effect (Slamecka & Graf, 1978), wherein producing a word from a cue during study leads to much better explicit memory than does simply reading the word. Interestingly, the generation effect typically is absent in implicit memory (e.g., Masson & MacLeod, 1992). By analogy to the generation effect, we would then expect that endogenous cues should lead to better memory performance than exogenous cues on an explicit test, but that this advantage might well be absent on an implicit test.

At first glance, a reasonable expectation would be that these cuing effects would apply only—or at least more—to the cued word than to the uncued word, given that the cued word is the one to which attention is directed. Under this perspective, on direct tests of explicit memory, an interaction would be expected between the type of cue and whether a word was or was not cued. But it may be that such cuing manipulations affect the extent of active processing for the whole display, mobilizing attention more for any stimuli present on an endogenously cued trial than on an exogenously cued trial. If this were to be the case, then the advantage of endogenous cues on explicit tests would be seen for both the cued and the uncued words. There would only be an effect of cue type, with no effect of whether a word was or was not cued and no interaction.

These are the hypotheses that we set out to test by manipulating cue type—endogenous versus exogenous—and whether a word was cued (signaled to be read aloud) or uncued. Experiment 1 used an indirect test of memory, where we would expect no influence of our cuing manipulations. Experiments 2 and 3 used a direct test of memory, where, if these early cues do influence memory, their impact should be observed.

2. Experiment 1

In the first experiment, the relation between attention and memory was tested with a perceptual implicit memory test. In the study phase, there were two words, one above the other, and one of them was cued randomly on every trial. When the cue was exogenous, it was an advance onset signal at the location of the cued word. When the cue was endogenous, it was an advance arrow signal at the center of the display that pointed to the location of the cued word. To ensure processing of the cue, the participants had to say the cued word aloud on each trial. In the test phase, memory for both cued and uncued studied words relative to baseline unstudied words was tested.

We selected speeded reading (naming) as our perceptual implicit test (MacDonald & MacLeod, 1998; MacLeod & Daniels, 2000; MacLeod & Masson, 2000). Here, the participants are asked to read aloud into a microphone each word that appears on the screen as fast as possible. The dependent measure is the latency of the reading response. The difference between reading times for the studied and new words is the measure of implicit memory, with faster response to previously studied words indicative of priming. Relative to other indirect tests, the speeded reading test helps to minimize the likelihood of conscious recollection in two ways: (1) the words are completely presented at test, reducing the need for problem-solving activities (see MacLeod & Masson, 2000) and (2) reading responses are quick and automatic (see Horton, Wilson, & Evans, 2001).

As discussed in the introduction, we expected that our attentional cuing manipulation would not influence performance on an implicit test. Thus, Experiment 1 should show no cuing effect, and provide a contrast to—a dissociation from—Experiments 2 and 3 where an explicit test may well be sensitive to these manipulations.

2.1. Method

2.1.1. Participants

Twenty-four undergraduate students (5 male) from an introductory course at the University of Toronto at Scarborough received course credit for their participation. The data of three participants were deleted from analysis because they had more than 20% errors in the study phase, leaving 21 in the final sample.

2.1.2. Materials

The pool of stimuli consisted of 283 four-letter words from the Thorndike and Lorge (1944) norms. These were all of the four-letter nouns (even if they were also verbs) that had frequencies of at least 10 per million in the norms.

For each participant, 96 words were randomly selected for the study phase. These were arbitrarily paired to create 48 pairs. In the test phase, there were 128 trials, of which 64 were old items from the study phase and 64 were new, unstudied items. Thus, only 32 of the 48 study pairs were actually tested. Of the 64 old items, 32 were from exogenously cued trials, 16 cued words and 16 uncued words. The other 32 were from endogenously cued trials, 16 cued words and 16 uncued words.

A practice sample of 12 words that did not appear in the study or test trials was constructed to familiarize participants with speaking into the microphone and minimizing speaking errors while doing the actual experiment. Another set of four examples of study pairs was constructed to show the participants the four different kinds of attentional cue trials that could appear. For these practice trials, the words were people's names.

2.1.3. Apparatus

This study was carried out on an IBM 486-compatible computer with a 14-in. color VGA monitor. The experiment was written in QuickBASIC 4.5, with millisecond accuracy timing routines taken from Graves and Bradley (1991). Response times were measured as the interval between the stimulus onset on the screen and the oral response of the participant into a microphone attached to the keyboard. Accuracy data were measured as the proportion of correct answers.

The background color of the screen was black (palate no. 0). The stimulus words were presented in lower case white letters (palate no. 15). The exogenous cue was a series of six asterisks presented in red (palate no. 12) at the location of one of the words (top or bottom) on a trial. The endogenous cue was a series of four arrows pointing down in green (palate no. 2) or pointing up in yellow (palate no. 14).

2.1.4. Procedure

The participants first read aloud 12 words to become familiar with speaking into the microphone. Then, the instructions for the study phase were shown on the computer screen and the four practice trials were presented. Note that the study phase was incidental in all three experiments: No mention was made of the upcoming memory test. Next, the experimenter asked the participants to describe what they had to do during the study phase; if they could not, the instructions were repeated. The participants were told to pay attention only to the cued word and to read that word aloud, ignoring the other (uncued) word on the screen.

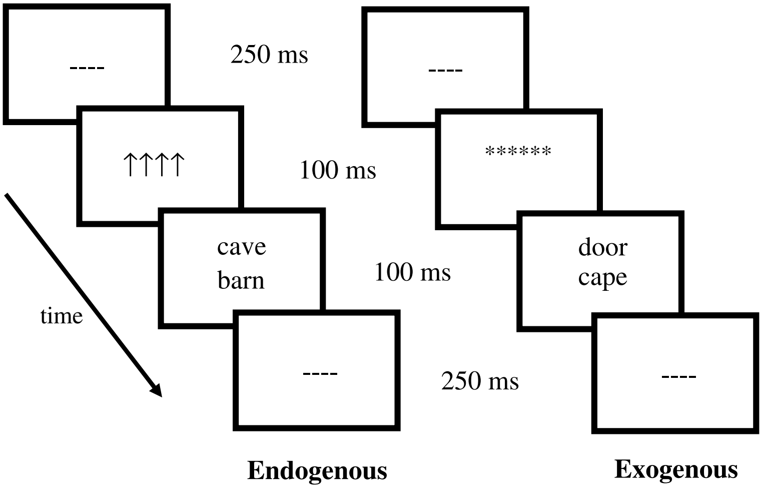

Fig. 1. Experiment 1: The sequence and timing of a trial. In the exogenous example, “cave” is cued and “barn” is uncued; in the endogenous example, “door” is cued and “cape” is uncued. The participant was to read aloud only the cued word on each trial.

Fig. 1 presents a diagram of the trial sequence and timing. In the study phase, each trial consisted of two words, one a single line above (line 11) and one a single line below (line 13) the center line of the computer screen. Before each trial appeared, a row of four white dashes (‘----’) was presented for 250 ms at the center of the screen (line 12) as an orienting stimulus. On each trial, one of the two words was cued either by an exogenous or by an endogenous cue, with type of cue randomized over trials.

The exogenous cue was a row of six red asterisks (‘******’) that appeared for 100 ms at the same location as one of the two words. This cue was one character longer at each end than the word, given that all words were four letters long. This was done to make the cue distinct from the word that it cued. Erasure of the cue occurred simultaneously with the onset of the two words. The endogenous cue was a row of four arrows (‘↑↑↑↑’ or ‘↓↓↓↓’) presented at the center of the screen for 100 ms. The arrows either pointed up (in yellow) to the top word or down (in green) to the bottom word. The color distinction made it easier for the participants to identify the cue. Again, the cues offset as the words onset.

The test phase consisted of an implicit speeded reading test. Before each word was presented, a row of four white dashes appeared at the center of the screen (line 12) for 250 ms. Then, a word was presented in white, also at the center of the screen, and remained until the participant said it aloud. The instructions were to read aloud each test word as quickly as possible.

2.2. Results and discussion

The primary dependent measure was response time (RT), although accuracy was also scored both in the study and the test phases. We first report the data from the study phase. The RT data showed no significant difference in time to read aloud exogenously cued words ($M = 721$ ms, $SE = 29.67$) versus endogenously cued words ($M = 730$ ms, $SE = 23.08$), $t(23) = 0.55$. The accuracy data confirmed the absence during the study of any cuing

Table 1
Experiment 1—Implicit speeded reading test phase: Means (and standard errors) for correct response time and accuracy as a function of cue type and whether a word was cued

	Exogenous		Endogenous		Unstudied
	Cued	Uncued	Cued	Uncued	
RT	527 (13.05)	542 (15.70)	535 (14.64)	532 (13.72)	546 (14.70)
Acc	.977 (.008)	.974 (.008)	.974 (.013)	.982 (.007)	.959 (.008)

effect between the exogenously cued words ($M = .927$, SE = .014) and the endogenously cued words ($M = .951$, SE = .010), $t(23) = 1.40$. Put simply, neither response times nor errors differed during encoding as a function of the type of cue or whether a word was cued.

We now examine the crucial data from the test phase. There were five within-subject conditions: a 2 (Type: endogenous versus exogenous) × 2 (Cue: cued versus uncued) factorial design for studied words plus the unstudied words baseline condition. Table 1 presents a summary of the means and standard errors for these five test conditions. All analyses to be reported in all experiments are one-way analyses of variance (ANOVAs), followed by a series of four planned comparisons: The first examines whether the four studied words conditions differed from the baseline, unstudied condition; the remaining three correspond to a standard 2 × 2 ANOVA.

For the RTs, the one-way ANOVA demonstrated an overall significant effect of condition, $F(4,92) = 4.55$, MSE = 287, $p < .01$. The first comparison indicated that there was indeed reliable priming, $F(1,23) = 15.37$, MSE = 3371, $p < .001$, with studied words (536 ms) about 10 ms faster on average than unstudied baseline words (546 ms). For the 2 × 2 analysis, no significant main effects emerged, either for Type, $F(1,23) = .07$, MSE = 773, or for Cue, $F(1,23) = 2.25$, MSE = 1443. A borderline significant interaction, $F(1,23) = 4.26$, MSE = 1702, $p = .051$, suggested that, when the cues were exogenous, cued words were read a little faster than uncued words, whereas when the cues were endogenous, there was no difference in reading speed for cued and uncued words.

For the accuracy data, there was no significant main effect on the one-way repeated measures ANOVA, $F(4,92) = 1.46$, MSE = .001. The first contrast did, however, reveal a significant effect, demonstrating that words presented in the study phase (.977) were more accurately read than were new words presented only on the test (.959), $F(1,23) = 17.74$, MSE = .007, $p < .001$. The other three contrasts, corresponding to the 2 × 2 analysis, revealed no significant effects for Type, Cue, or their interaction, all Fs < 1.

These results indicate that our attentional manipulations had no reliable influence on later implicit memory, at least as measured by speeded reading, which has proven to be a particularly sensitive index of priming (see, e.g., MacLeod & Daniels, 2000; MacLeod & Masson, 2000). The suggestive interaction might indicate that exogenous cues draw attention toward the cued word and thus away from the uncued word, leading to better perceptual implicit memory for these cued words. This is a tantalizing possibility, but one that will require further investigation to confirm or refute. Otherwise, the results are consistent with these attentional cues not influencing implicit memory at all.

Next, we turn our attention to how these attentional manipulations affect later explicit memory, given that direct memory tests are more sensitive to other attentional manipulations than are indirect memory tests (e.g., MacDonald & MacLeod, 1998; Szymanski & MacLeod, 1996). Examining the effect of attentional cuing on explicit memory is the purpose of Experiments 2 and 3, and the primary focus of this article.

3. Experiment 2

Experiment 2 was set up exactly as Experiment 1, except that memory was now tested with a direct test of explicit memory. This test was yes/no recognition. Here, the participants should of course be able to distinguish studied words (whether cued or uncued) from unstudied new words, demonstrating overall remembering. But now endogenous and exogenous cuing may well influence memory.

As set out at the end of our introduction, endogenous cues, being more under subject control and more likely to induce active processing, would be expected to produce relatively better memory than exogenous cues, which are handled more automatically and are more likely to induce passive processing. So we expected endogenous cues to lead to better memory than exogenous cues, which would manifest as a main effect of the type of cue. If exogenous cues induce active processing only of the cued word, then there might also be a main effect of whether a word is cued or uncued and there should be an interaction. But it also seemed quite conceivable to us that the cue manipulation would affect both words, with the cue inducing a set that affected the processing of all of the stimuli present on a given trial. If so, then there would be only a main effect of the type of cue.

3.1. Method

3.1.1. Participants

Twenty-three different students (10 male) from the same pool received course credit for taking part. Five participants who made more than 20% errors in the study phase, apparently because of language difficulties, were replaced.

3.1.2. Materials and apparatus

Exactly the same materials and apparatus were used as in Experiment 1.

3.1.3. Procedure

The procedure was the same as in Experiment 1 apart from the change in the test phase: A recognition test was substituted for the speeded reading test. The participants responded "yes" (by pressing the 'z' key) or "no" (by pressing the '/' key) to indicate whether they thought they had seen each test word during study. Words were to be considered "old" regardless of the cue type and regardless of whether they had been cued (spoken aloud) or uncued. Both the latency and accuracy of recognition were recorded.

3.2. Results and discussion

Consider first the study data. For the reading RTs, there was no difference at study between exogenously studied trials ($M = 742$ ms, SE = 30.47) and endogenously studied trials ($M = 738$ ms, SE = 26.92), $t(22) = 0.41$. There also was no difference in reading accuracy

Table 2
Experiment 2—Explicit recognition test phase: Means (and standard errors) for correct response time and for "Yes" responses as a function of cue type and whether a word was cued

	Exogenous		Endogenous		Unstudied
	Cued	Uncued	Cued	Uncued	
RT	908 (36.95)	920 (31.38)	923 (32.00)	922 (27.99)	1072 (40.14)
"Yes"	.400 (.033)	.429 (.030)	.459 (.030)	.457 (.030)	.198 (.023)

Note. "Yes" responses are hits except for the unstudied condition, for which they are false alarms.

between exogenously studied trials ($M = .927$, SE = .017) and endogenously studied trials ($M = .943$, SE = .012), $t(22) = .73$. As in Experiment 1, these results indicate that cued words in both conditions were located equally well, with an equal number of mistakes and quite equivalent RTs.

Turning to the critical test phase data, the test was now explicit recognition. Table 2 presents the relevant RT and accuracy means and standard errors for the five conditions. There was a significant overall effect of condition, $F(4,88) = 7.84$, MSE = 14,087, $p < .001$. As in Experiment 1, four planned contrasts were conducted. The first revealed that Yes responses (false alarms) to new words (1072 ms) were made significantly more slowly than were Yes responses (hits) to studied words (918 ms), $F(1,22) = 21.24$, MSE = 412,438, $p < .001$. The other contrasts corresponding to the 2×2 design on studied items showed that there were no effects of Type, Cue, or their interaction, all Fs < 1. Put simply, for recognition test RT, there was only evidence of overall memory for all words that had been presented in the study phase, and no differential effect of cuing or of cue type.

The accuracy data, however, showed a different pattern. The overall effect of condition was significant, $F(4,88) = 23.96$, MSE = .011, $p < .001$. The first comparison showed that hits (.436) were much more likely than false alarms (.198), $F(1,22) = 126.85$, MSE = .165, $p < .001$. Of primary interest, there was a significant main effect of Type, $F(1,22) = 4.71$, MSE = .017, $p < .05$, indicating that words in the endogenous condition (.458) were better remembered than were words in the exogenous condition (.414)—regardless of whether they were cued. There was no main effect of Cue, nor was there any interaction, both Fs < 1.

Consistent with our hypothesis, the endogenous cue appears to have caused more active processing and elaboration, resulting in better explicit memory performance for endogenously cued as opposed to exogenously cued words. But intriguingly, this endogenous cuing advantage applied to both of the words on the screen on a given trial, not just to the cued word. In the endogenous condition, the participants actively had to look for the word to which the arrow was pointing, leading them to be more engaged in processing all stimuli. Poorer memory in the exogenous condition might result from the participant's attention being automatically drawn to the location of the cued word, thereby invoking a more passive, less elaborative processing approach.

4. Experiment 3

Although reliable, the effect of the type of cue was not large in Experiment 2, so we chose to replicate it in Experiment 3. One minor change was made: Because the overall memory performance was rather low in Experiment 2, we tried to improve it in Experiment 3 by reducing the number of study trials by 33%. As it turned out, this change did not alter the pattern, so we will not discuss it further. We expected to obtain a similar pattern of results to that observed in Experiment 2: Better memory was expected for words in the endogenous condition than for words in the exogenous condition, and no effect of whether a word was cued or uncued was expected for either type of cue.

4.1. Method

4.1.1. Participants

Twenty-four different undergraduate students (3 male) from the same pool received course credit for participating in the experiment.

4.1.2. Materials

All of the stimulus materials from Experiment 2 were used in Experiment 3, except for two changes. This time, there were only 32 study trials instead of 48, with all 32 study trials tested in the test phase. The exogenous cue was changed from a row of six red asterisks to a row of four red asterisks.

4.1.3. Apparatus and procedure

These were exactly the same as in Experiment 2.

4.2. Results and discussion

We first examined the study phase data. For the reading RTs, for the first time, there was a significant difference between exogenously and endogenously studied trials, $t(23) = 3.65$, $p < .01$. The participants were 34 ms faster in reading aloud the exogenously cued words ($M = 704$ ms, SE = 19.62) than the endogenously cued words ($M = 738$ ms, SE = 18.54). For the accuracy data, there was no significant difference between the exogenously ($M = .912$, SE = .013) and the endogenously ($M = .893$, SE = .019) studied trials, $t(23) = 0.81$.

Table 3 presents the data from the test phase. Consider first the response time data. Again, there was a significant effect of condition, $F(4,92) = 4.13$, MSE = 25,809, $p < .01$. The first planned contrast revealed that false alarms (1031 ms) were significantly slower than hits (914 ms), $F(1,23) = 11.43$, MSE = 455,667, $p < .01$, demonstrating discrimination of the

Table 3
Experiment 3—Explicit recognition test phase: Means (and standard errors) for correct response time and for "Yes" responses as a function of cue type and whether a word was cued

	Exogenous		Endogenous		Unstudied
	Cued	Uncued	Cued	Uncued	
RT	968 (61.12)	886 (38.43)	864 (33.04)	940 (40.67)	1031 (48.48)
"Yes"	.393 (.045)	.430 (.041)	.430 (.032)	.471 (.039)	.209 (.027)

Note. "Yes" responses are hits except for the unstudied condition, for which they are false alarms.

studied words from new, unstudied words. The main effects of Type and of Cue were nonsignificant, both Fs < 1. The interaction approached significance, $F(1,23) = 4.16$, MSE = 144,025, $p = .053$, but the pattern did not make sense: Cued words under the endogenous condition and uncued words under the exogenous condition seemed to be responded to a little faster than uncued words under the endogenous condition and cued words under the exogenous condition. We take this incomprehensible (and nonsignificant) pattern to be spurious.

The same analysis on the accuracy data showed that the overall effect of condition was significant, $F(4,92) = 25.62$, MSE = .010, $p < .001$. The first comparison demonstrated that hits (.431) were much more likely than false alarms (.209), $F(1,23) = 98.00$, MSE = .193, $p < .001$, as in Experiment 2. Of primary interest, there was a significant main effect of Type, $F(1,23) = 4.71$, MSE = .034, $p < .05$, indicating that words in the endogenous condition (.450) were better remembered than were words in the exogenous condition (.412) regardless of whether they were cued, again the same pattern as Experiment 2. The main effect of Cue approached significance, $F(1,23) = 4.04$, MSE = .036, $p = .056$, but did not make sense, with recognition of uncued words (.450) slightly better than that of cued words (.412). There was no interaction, $F < 1$.

The data of Experiment 3 closely replicated those of Experiment 2, underscoring that early attentional manipulations can affect later explicit memory. Words presented in the endogenous condition during the study phase again were better remembered than words presented in the exogenous condition. These results suggest that words were better remembered when attention was actively engaged instead of being passively engaged on a study trial.

5. Comparing across the experiments

We have presented evidence that endogenous cuing produced an advantage over exogenous cuing on the explicit recognition test used in Experiments 2 and 3, but not on the implicit speeded reading test used in Experiment 1. To bolster the analyses already presented, we conducted analyses across the experiments, recognizing the hazards of such comparisons. Because of the different principal dependent variables in the experiments—speeded reading response time in Experiment 1 and recognition accuracy in Experiments 2 and 3—we first converted all of the scores of each experiment to a single set of z scores. We then conducted $2 \times 2 \times 2$ ANOVAs with a single between-subjects factor (Experiment) and two within-subject factors (Type and Cue). The focus was on the Type by Experiment interaction, so that is all that we will consider here, although we note that there were no peculiarities in the remaining main effects or interactions. For the comparisons of Experiments 1 and 2 and of Experiments 1 and 3, the critical interaction was reliable in both cases ($p < .05$); for the comparison of Experiments 2 and 3, this interaction was not reliable ($p > .50$). Clearly, then, the effect of cue type was absent for our implicit test and present—consistently across two experiments—for our explicit test.

6. General discussion

Our results clearly show that early attentional manipulations can have a measurable influence on later explicit memory. Specifically, the results of Experiment 2 showed an advantage in explicit memory—as measured by a recognition test—for words presented in the endogenous condition compared to words presented in the exogenous condition. This result was replicated in Experiment 3, demonstrating that, although not large, the effect is a reliable one. At least under some circumstances, then, endogenously cued attention has a beneficial effect on later memory. Furthermore, the results somewhat surprisingly did not reveal any positive exogenous cuing effects, suggesting that exogenous cuing at this early attentional level does not influence later explicit memory.

Considering the consistent pattern of results over Experiments 2 and 3, it does appear that endogenously cued attention produces a more active and involved learning approach. This approach encourages more elaborative processing, which in turn leads to better memory for words experienced in the context of an endogenous cue. This view assumes that exogenously cued items are more passively processed, because attention is grabbed by a stimulus characteristic and little active involvement is demanded.[3]

Decades of research (e.g., Craik & Lockhart, 1972; Morris et al., 1977; Slamecka & Graf, 1978) have proven that active and involved learning enhances memory performance, whereas passive learning has considerably less beneficial influence on memory. Indeed, this idea of active learning being better than passive learning can be traced back at least to the perceptual learning studies of Held and Hein (1963), where cats learned to move around a new environment better if their experience was active than passive. The current results clearly show that, even at this very early stage of attention, there is a memory advantage for words presented in an endogenous cuing condition that are consequently more actively processed.

The current findings also fit nicely with earlier studies about the relation between attention and memory (MacDonald & MacLeod, 1998; Mulligan, 1998; Szymanski & MacLeod, 1996). Very little effect of the attentional cuing manipulation was found on the perceptual implicit memory test, whereas results on the explicit memory test were consistently influenced—albeit modestly—by these same manipulations. This confirms that explicitly tested memory is generally more sensitive to attentional manipulations than is implicitly tested memory, even when the attentional manipulations used were earlier in processing than was the case in the previously published studies.

These results not only complement the recently conducted experiments on attentional effects on memory that we have described; they are also consistent with the transfer-appropriate processing analysis of memory (Morris et al., 1977; Roediger, 1990). The current attentional manipulations demonstrated a different pattern of results on implicitly and explicitly tested memory. Yet our results are in line with earlier arguments made by Mulligan (1998) and Roediger (1990), who suggested that the original transfer-appropriate processing view is in need of some revision. Transfer-appropriate processing would seem to predict that any manipulation that disturbs perceptual processing will reduce perceptual priming and also performance on a perceptual explicit test.

The present results showed that perceptual attentional manipulations had little effect on a later perceptual implicit memory test, whereas these manipulations did affect explicit memory tests more strongly. Consequently, somewhat counter to intuition, perceptual implicit tests seem to be less sensitive to early attentional manipulations than are explicit

[3] Because the cues were always 100% informative in both the exogenous and endogenous situations, a top down element was present even in our exogenous condition. In this sense, we were comparing a situation consisting of exogenous plus an unknown amount of endogenous cuing to a purely endogenous situation. This does not undermine our key point, however, which is that more endogenous cuing benefits memory.

memory tests.[4] The transfer-appropriate processing framework may need to put more emphasis on the implicit versus explicit test instructions than on the perceptual versus conceptual distinction to account for the dissociation in memory.

Why were there no differential cuing effects in either cuing condition? It may simply be that the cues were too early in the stream of processing for an effect of cued versus uncued items to emerge. The cue on a given trial may instead simply have set the global encoding context for that entire trial. An endogenous cue oriented the participant to a more elaborative set for processing both words on that trial than would have been the case for an exogenous cue.

Consider further what might be happening in the endogenous condition. After having seen the arrows pointing up or down, the participants had to store the arrows' direction in their working memory (Kane & Engle, 2000, 2003). They then had to attend to both words, which also had to be kept in working memory. Combining these two types of stored information, the participants could then decide which word was cued by the arrows and say that word aloud. Successful responding necessitated that attention be paid to both words, whether cued or uncued, so memory for these words was equally good and no differential endogenous cuing effect occurred. The elaboration in the endogenous condition would then be seen as a benefit due to active processing in working memory. Put another way, our contention is that it is the post-registration conceptual processing in the endogenous cuing condition that accounts for better memory in that condition; this conceptual processing may not occur in the exogenous cuing condition.

One might hypothesize instead that better memory in the endogenous cuing condition was due to longer exposure and hence longer study time, which could have allowed more elaborate processing of these words. But latency data from the study phases contradict this argument. Response time was not significantly longer to name the endogenously cued words in Experiment 2 despite better memory for words in that condition. Although in Experiment 3 it did take participants longer to name the endogenously cued words, the memory result was identical to that of Experiment 2. We also know from the levels of processing studies (Craik & Lockhart, 1972) that study time is not as good a predictor of retention as is the nature of processing.

Given these consistent results, further investigation of the relation between early visual attentional cuing effects—especially endogenous cuing effects—and subsequent memory would seem warranted. In particular, it would be interesting to conduct similar studies using a conceptual implicit test (e.g., implicit test of word association or general knowledge test; Mulligan, 1998). If endogenous cuing were to influence conceptual implicit memory results, this would support the idea that such cues induce elaborative processing, and there would be further support for an adjusted version of the transfer-appropriate processing framework (Mulligan, 1998; Roediger, 1990).

Finally, it would be worthwhile to investigate the working memory hypothesis just discussed, exploring whether this is the mechanism underlying the current effect. Certainly, voluntary allocation of attention is related to working memory (Corbetta, Kincade, & Shulman, 2002; Kane & Engle, 2000, 2003; see also De Jong, 2001). Although it is not easy to find an appropriate paradigm to investigate this hypothesis, one might think about a

[4] It would be interesting to extend the implicit memory examination to conceptual tests and indeed to contrast perceptual and conceptual implicit tests directly, given that conceptual implicit tests seem more sensitive to attentional manipulations (e.g., Mulligan, 2003).

paradigm in which one disturbs maintaining the words in working memory, or a paradigm that disrupts putting words into working memory.

Returning to the goal of the present study, we sought to investigate the influence of early attentional cuing manipulations on later implicit and explicit memory. Even though one might not expect these early attentional manipulations to have an impact on later memory, given the extensive processing that follows initial registration, the results of the present study clearly showed that they did. Relative to early exogenous cuing of attention, early endogenous cuing had a beneficial effect on later explicit—but not implicit—memory. These results suggest that memory performance is already influenced by a very initial stage of attention, which may set the processing approach on that study trial. This is consistent with the argument that active processing at any point in the stream of processing can benefit subsequent conscious memory.

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