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The influence of attention at encoding on direct and indirect remembering

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Abstract

The relation between attention at encoding and direct (i.e., recognition) versus indirect (i.e., rapid reading) remembering was investigated. In Experiments 1 and 2, color of print indicated whether to read an individual word aloud or to ignore it. This attentional manipulation reduced direct but not indirect remembering for the ignored words relative to the attended words. Apparently direct remembering is extremely dependent on attention at encoding. In Experiment 3, however, presenting two words simultaneously at study, with color now signifying which word to read and which to ignore, eliminated this dissociative effect of attention. Ignored words were not remembered on either test, although attended words were remembered well on both. Mere exposure is not sufficient to produce indirect remembering: Stimuli must be attended. Ignoring one stimulus in favor of processing another stimulus that is simultaneously presented and equally salient may prevent even the minimal attentional requirements of indirect remembering from being met, let alone the more stringent requirements of direct remembering. © 1998 Elsevier Science B.V. All rights reserved.

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1. Introduction

To perform well on traditional tests of memory, subjects must consciously recollect previously encoded events (Johnson and Hasher, 1987; Richardson-Klavehn and Bjork, 1988; Roediger and McDermott, 1993). Free recall and recognition tests are the hallmark examples of such tests, which have long been the primary tools for the study of memory. These tests may be referred to as *direct* tests, in that subjects are encouraged to make explicit contact with one or more previous encoding episodes. In the past 15–20 years, however, memory researchers have become increasingly intrigued by another class of memory tests: indirect tests.

On *indirect* tests of memory, subjects are not asked to refer back to a prior episode, despite its relevance to the task at hand. Often, though not necessarily, the relevance of the prior episode or study phase is even concealed from subjects. In these tasks, evidence of retention of the encoding episode is usually revealed by facilitated (i.e., faster or more accurate) performance for items that were previously presented compared to equivalent items that were not previously presented. This facilitated performance is usually referred to as *priming* or *repetition priming*. Generally, the instruction to refer or not to refer to previously presented material has been used as an operational distinction between direct and indirect tests (Roediger and McDermott, 1993).

There are numerous examples of indirect tests of memory. The word fragment completion task (Tulving et al., 1982) involves presenting words with letters omitted and requiring subjects to fill in the missing letters. When a solution to a fragmented word was previously presented, subjects more often offer correct completions. In the masked word identification task (also referred to as the perceptual identification task; Jacoby and Dallas, 1981), words – some previously studied and some new – are presented to subjects very briefly and then masked. Subjects are usually able to identify more studied words than unstudied words despite no instructions to use memory or to refer to the study list (e.g., Masson and MacLeod, 1992). A further example of an indirect test is the rapid reading procedure (also called pronunciation or naming; e.g., Scarborough et al., 1979) where latencies to read words that were previously presented are normally shorter than are latencies to read new, unstudied words (e.g., MacLeod, 1996). All of these tests have been used as indirect measures of memory, along with an ever-growing battery of others.

Attentional manipulations at encoding have been found to affect direct but not indirect tests of memory (Parkin et al., 1990; Szymanski and MacLeod, 1996). Research shows that dividing or diverting attention from items at study impairs performance on subsequent direct tests but does not similarly impair performance on indirect tests. This dissociation will be the focus of the experiments that we will present. Before describing our experiments, we will review previous investigations of how attention at study affects performance on direct versus indirect tests of memory.

1.1. *Attention and its effect on performance on direct and indirect tests of memory*

Research has begun to emphasize the interplay between attention and memory as measured by different types of tests. Early on, Eich (1984) used a dichotic listening procedure, having participants shadow prose to the attended ear while hearing word pairs consisting of a homophonic noun preceded by an adjective that biased its interpretation (e.g., taxi-FARE) in the unattended ear. Although on a subsequent recognition memory test participants did not recognize the words from the unattended ear, they demonstrated the appropriate bias in an oral spelling test (e.g., spelling "fare" rather than "fair"). This finding reveals preserved priming on an indirect test for items that were not attended, despite no evidence of memory for these items on a direct test.

Parkin et al. (1990) examined the effect of divided attention at study by asking participants in a full attention condition to complete a sentence verification task only and participants in a divided attention condition to perform sentence verification and tone monitoring tasks simultaneously. The sentence verification task involved reading sentences and judging whether they made sense; the tone monitoring task consisted of listening to a series of tones occurring every 3–7 s and indicating for every tone whether it was high, medium, or low frequency. After a 24-h delay, participants performed a recognition test and a word fragment completion test. As expected, Parkin et al. found recognition to be much poorer under divided attention conditions than under full attention conditions. On the word fragment completion test, however, divided attention at encoding had no ensuing effect: both groups showed equivalent priming for studied words. These results suggest that implicit remembering occurs despite constraints on attentional resources at study. Divided attention at study is not so kind, however, to performance on direct tests, which suffers substantial impairment. This conclusion was strengthened by the corresponding findings of Parkin and Russo (1990) using picture completion as both the direct and the indirect measure of memory.

Szymanski and MacLeod (1996) also examined the impact of selective attention at study on subsequent direct and indirect memory tests. During encoding, participants read some words aloud and named the print colors of others. In the color-naming study phase, the word was ignored whereas the color was attended. At test, participants either performed a direct recognition test or an indirect lexical decision test. In both tests, words from the study phase appeared among new words. Szymanski and MacLeod found that words that were read at study were better recognized than words that were color-named at study. The repetition priming in the lexical decision task, however, was equivalent for words that were read and words that were color-named at study. Szymanski and MacLeod concluded that successful implicit remembering occurs once a low attentional threshold is met, and that further attention confers little additional benefit. Their study provides yet another illustration of dissociated performance on direct and indirect tests of memory.

Although many studies have found preserved priming on an indirect test despite impaired performance on a direct test following reduced attention at study, recent evidence has emerged indicating that the effect of attention at encoding on direct and indirect remembering is not as straightforward as it first seemed. [2] Noteworthy among these, Wood and Cowan (1995) investigated both types of tests in a series of selective listening experiments. Participants were asked to ignore passages presented to one ear while attending to and shadowing passages presented to the other ear. A segment of backward speech was embedded in the passage presented to the unattended ear, and participants were later asked to indicate whether they could recall anything odd happening in the unattended ear. Although some did remember hearing a switch to backward speech, their recollection occurred at a cost to on-line shadowing. For participants who detected the shifts, errors in shadowing occurred about 15 s following the shift from forward to backward speech in the unattended ear. Evidently, remembering did not occur in the absence of attention at study. In addition, both direct and indirect tests of memory revealed little to no memory for the content of the unattended message in which the backward speech had been embedded. These findings suggest that success on both direct and indirect tests requires attention at encoding.

In his Experiment 10, Phaf (1994) also investigated the effect of attention at encoding on direct and indirect remembering. Participants were presented two words simultaneously on each trial, one to the left and one to the right of fixation. After

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[2] In quite a different procedure, Logan and Etherton (1994) explored how attention is involved in the learning that occurs during automatization, a situation which can be seen as a type of continuous indirect test. They used a simplified search task in which subjects saw two words simultaneously on each trial (e.g., steel-Canada) and had to indicate whether one of them was a member of a previously specified taxonomic category (e.g., metal). Targets appeared repeatedly over the sequence of search trials. The search task was performed under focused attention, divided attention, or dual task conditions. Interest centered on what subjects would learn about the word that was paired with the target word (e.g., steel could occur with a different word on every occurrence or it could appear with Canada repeatedly). Learning was measured by the change in performance across repetitions of stimuli as well as by the impact of transfer to re-paired items.

Across a series of seven experiments, subjects showed clear evidence of sensitivity to repeated pairings under divided attention conditions (no visible cue to the target word) and under dual task conditions (subjects had to perform a secondary task in addition to the search task on each trial). In both cases, changing pairings on the transfer trials disrupted performance, suggesting that the original pairing had been learned and was now interfering. However, under focused attention conditions, where a cue (a color or an arrow) indicated the critical word in the pair, learning of co-occurrence did not occur, with transfer unaffected by changed pairings.

Subsequent work by Logan et al. (1996) and by Boronat and Logan (1997) has extended the initial findings, with the latter study in particular indicating that attention appears to be important both at the time of encoding and at the time of retrieval. We believe that it is reasonable to see their search task as a type of indirect measure of memory, in that subjects do not need to remember prior item occurrences to perform subsequent category searches successfully, although their demonstrated priming shows that they clearly do. So attention does seem to affect indirect test performance in this sort of setting. However, this setting is very different from the sort more typically used in contrasting direct and indirect test performance, and unfortunately there was no direct test with which to contrast the indirect pattern in these studies. It remains possible, then, that direct learning and/or recollection of pairs was contaminating their indirect test performance. The frequent repetition of items in the Logan and Etherton (1994) procedure may even have promoted such a strategy in their subjects. Nevertheless, one goal of continuing research should be to bring together the seemingly disparate lines of research that all relate to the question of how attention affects performance on direct and indirect tests of memory.

a 200-ms delay, an arrow appeared pointing to one word, instructing participants to read it aloud. Participants were to attend only to the cued word, and were urged to ignore the other word. Three tests were later administered. One group did a word-stem completion test, with unique three-letter cues corresponding to studied or unstudied words. Another group did a masked word identification test, where each test word briefly appeared inside a mask. Finally, a third group did a free recall test. The free recall test showed essentially no memory for the ignored words, consistent with the need for prior attention on direct tests. More surprisingly, however, both indirect tests also demonstrated impairment for words that were ignored at study. Even though there was still reliable priming for the ignored words, participants showed more priming for attended words. In contrast to the previously described results, these findings suggest that attention may play a role in both direct and indirect remembering.

The most common finding is that there is virtually no effect of decreased attention to items at study on later indirect tests despite seriously detrimental effects on later direct tests (Eich, 1984; Szymanski and MacLeod, 1996). Although this pattern is not uncontested, it suggests that success on indirect tests does not depend on attention at encoding despite the fact that success on direct tests depends greatly on it. The following contention expresses this view about indirect remembering: "...the memory processes underlying priming effects are not open to conscious inspection and should not be disrupted by experimental manipulations that reduce the subjects' degree of conscious involvement with the initial learning task" (Parkin et al., 1990, p. 510). Others also argue that indirect remembering is independent of attention and that automatic sensory registration or data-driven processing is sufficient to facilitate reprocessing of studied items on indirect tests (Hayman and Tulving, 1989; Roediger, 1990).

The objective of the present study was to explore further this interplay between attention and memory. The aim was to increase clarity concerning the contribution of attention at study to subsequent remembering as measured by these two classes of test, direct and indirect. Do all reductions in attention at encoding, no matter how slight, produce declines in performance on direct tests? Do all reductions in attention at encoding, no matter how extreme, fail to affect indirect remembering? Experiments 1 and 2 investigated whether direct remembering would be affected by a subtle attentional manipulation. The goal was to examine the sensitivity of direct remembering to even slight reductions of attention during encoding. In Experiment 3, the primary objective was to create a dramatic attentional manipulation at study to determine whether indirect remembering would be reduced if the manipulation of attention was sufficiently extreme.

2. Experiment 1

The aim of Experiment 1 was to investigate the effect of a subtle attentional manipulation at encoding on direct and indirect remembering. In most previous studies, attention to items has been limited either by competing stimuli (i.e., selective attention situations) or by competing responses (i.e., divided attention situations). In these cases, the attentional limitations on processing of tested items have been quite severe and usually have resulted in seriously impaired performance on direct tests (Eich, 1984; Szymanski and MacLeod, 1996; Wood and Cowan, 1995). The central question in the present experiment was how sensitive direct remembering is to decreases in attention at encoding. This question addresses the issue of attentional requirements for direct remembering.

The objective of the manipulation was to decrease the attention paid at study to some items relative to others, without presenting a competing stimulus or requiring a competing response. To accomplish this, participants were instructed to read aloud individual words presented in red but to respond 'pass' to individual words presented in white. The expectation was that, despite no explicit instructions to ignore the white words or to decrease attention to them, participants would consider the red words more important and thus attend to them more than to the white words. Color signalled the degree of attention to be paid to a word as well as how to respond appropriately to it. For red words, in addition to identifying its color, the word had to be identified and read aloud for proper responding. For white words, however, the only necessary action was to determine the color of the stimulus, after which processing could be halted and the response 'pass' could be provided.

2.1. Method

Participants: Twenty introductory psychology students at the University of Toronto at Scarborough participated in the experiment in exchange for bonus credit in their course.

Stimuli: A set of 120 words, each with estimated frequency of 30 or above out of a million, served as the materials for all experiments (Thorndike and Lorge, 1944). These words appear in Appendix A. Each participant received a uniquely randomized set of words for the study phase, and for each of the direct and indirect test phases. Words subtended 0.4° of visual angle when viewed at a distance of 57 cm (the approximate viewing distance in the experiment).

Apparatus: An IBM 486-compatible microcomputer with a 14-in. color VGA monitor was used for testing. The controlling program was written in QuickBasic 4.5 using the routines provided by Graves and Bradley (1987, 1988) to achieve millisecond timing accuracy. Response times were measured as the interval between the stimulus onset and the participant's oral response into a microphone that was interfaced to the computer. Accuracy was scored on-line by the experimenter.

Procedure: Participants were informed that they were taking part in a study of reading and reading speed. The experiment consisted of three phases: (1) study, (2) indirect test, and (3) direct test. During the study phase, participants saw 80 words, half printed in red and half printed in white, randomly intermingled. They were to read aloud the words printed in red at an average reading pace, but to respond 'pass' to the words printed in white. Participants were given no further instructions, nor were they informed that they would be tested on their memory for these words.

On each study trial, an orienting stimulus (**********) appeared at the center of the computer screen for 500 ms, followed by a blank screen for 500 ms. The colored word stimulus then appeared and remained on the screen until the participant spoke his or her response. The experimenter advanced to the next trial by pressing a key corresponding to the accuracy of the participant's response (i.e., whether they read the red words correctly or incorrectly, or whether they correctly responded 'pass' to the white words).

On the indirect test of memory, 20 of the red words and 20 of the white words randomly selected from the study phase were presented mixed together with 20 new words. The other 20 red words and the other 20 white words from the study phase appeared on the direct test of memory, mixed with 20 new words. In this way, there was no overlap of the words presented on the direct and indirect tests, permitting within-subject testing. The indirect test always preceded the direct test because the risk of contamination between tests is less in this direction.

The indirect measure of memory was rapid reading (MacLeod, 1996; MacLeod and Masson, 1997). In this task, participants are asked to read aloud each word that appears on the screen as quickly as they can, speaking their responses into the microphone. The latency of their reading response is the dependent measure, with the time difference between studied words and new words providing an index of implicit remembering. It is well established that previously studied words are read more quickly than are words new to the experiment (Scarborough et al., 1979). Our objective was to compare memory for words to which participants had responded 'pass' at study with memory for words that had been read aloud. As an indirect test, rapid reading has the virtues of (1) completely exposing the word and not requiring any problem-solving activity, and (2) being an extremely quick, automatic response, unlikely to be contaminated by conscious recollection (for more on this argument, see MacLeod, 1996; MacLeod and Masson, 1997).

As in the study phase, each stimulus on the indirect rapid reading test was preceded by an orienting stimulus (**********) for 500 ms and a blank screen for 500 ms. The word remained on the screen until the participant responded orally into the microphone. The word 'Ready?' then appeared on the screen as an indication to the experimenter to score the accuracy of the participant's response. During the indirect test, words that had appeared in white during the study phase were again presented in white and words that had appeared in red were again presented in red. This was done so that the words would be physically identical at study and at test because previous studies have shown that even slight alterations in a word's appearance from study to test can alter any benefit of reprocessing (e.g., Snodgrass and Hirshman, 1994). For the 20 new words, half appeared in red and half appeared in white, with the colors of these new words randomized anew for each participant.

The direct test of memory was a recognition test. The 40 previously studied words were also presented in the same color at test as they had appeared at study. Half of the 20 new words were presented in red; half were presented in white. The participant's task was to identify the words previously encountered on the study list, regardless of color. Participants were informed that none of the words from the rapid reading test were included on the recognition test. A trial proceeded as follows: (1)

An orienting stimulus (*********) was presented for 500 ms, (2) a blank screen appeared for 500 ms, (3) the test word was presented in either red or white, and (4) the participant pressed the key marked 'O' for old (the apostrophe key) or the key marked 'N' for new (the letter A key). Participants were informed that they were not being timed on their old/new decisions.

2.2. Results

Indirect test: A one-way repeated measures analysis of variance (ANOVA) was conducted on the mean latencies from the indirect rapid reading test, with encoding condition (read at study, 'pass' at study, and new) as the lone within-subject variable. The mean latencies used in the analyses and shown in the first column of Table 1 included only words that were responded to correctly at study and at test. The ANOVA was significant, $F(2,38) = 4.88$, MSe = 606.60, $p < 0.025$. A planned contrast comparing the mean latencies for new words to those for both types of old words combined was also significant, $F(1,19) = 14.76$, MSe = 2408.03, $p < 0.001$, indicating longer latencies for new words. This priming effect of 14 ms attests to the fact that studied words were indirectly remembered. The second orthogonal contrast comparing the mean latencies for words read at study versus those passed on at study was nonsignificant, $F < 1$. This indicates that studied words, regardless of whether they were read aloud or passed, were indirectly remembered equally well. As Table 1 shows, accuracy on this task was extremely high, such that most participants made no errors at all, so error analyses are not reported.

Direct test: A second one-way repeated measures ANOVA, with encoding condition (read aloud vs. pass response) as the within-subject variable, was performed on the d' scores for the recognition test. There was a significant difference between these d' scores, $F(1,19) = 68.17$, MSe = 0.19, $p < 0.001$, with better recognition for words that were read aloud at study than for those to which participants had responded 'pass' at study.

2.3. Discussion

There was a dissociation in participants' performance on the direct and indirect tests in Experiment 1. Not surprisingly, based on previous studies (Eich, 1984; Par-

Table 1

Experiment 1: Means and standard errors for correct response times (RT in ms) and error proportions on the rapid reading test, and for d' scores on the recognition test, as a function of encoding condition

Encoding condition	Rapid reading				Recognition	
	RT		Error		d'	
	Mean	SE	Mean	SE	Mean	SE
Read aloud	573	13.75	0.003	0.00	1.77	0.15
Respond 'pass'	573	19.28	0.008	0.00	0.63	0.10
New	587	17.37	0.003	0.00	–	–

kin et al., 1990; Szymanski and MacLeod, 1996), the attentional manipulation did not affect priming on the indirect rapid reading test of memory. Even this subtle attentional manipulation, however, did affect performance on the direct recognition test. This pattern of results is quite common (e.g., Parkin et al., 1990; Szymanski and MacLeod, 1996).

The key finding was that, despite what appeared to be only slight attentional biasing (i.e., read some words aloud and respond 'pass' to others, inspecting all of them), performance on a direct test was significantly affected. It appears that direct remembering is highly sensitive to attentional manipulations at encoding. The greater the attention directed toward the stimulus at encoding, the better the performance on a subsequent recognition test. In the present study, participants were not prevented from attending to the words to which they were supposed to respond 'pass.' They were further not explicitly instructed that these words were less important. In fact 'pass' words could have been processed identically to read words apart from overt responding. Despite this, words to which participants responded 'pass' were less well remembered on a direct test.

It should be kept in mind that participants were informed that they were taking part in a study of reading and reading speed. They had no reason to expect any words to reappear on a subsequent test, either direct or indirect. It seems likely, then, that in the interest of efficient performance, participants processed both types of words as far as was required: Red words required color, lexical, phonological, and likely semantic processing whereas white words had only to be processed for color. The processing necessary to ascertain the color of a word at encoding appears less successful in engaging the processes that enhance subsequent effortful retrieval. By contrast, this processing is sufficient to enhance subsequent rereading of the word as evidenced by intact priming.

On direct tests, the more contextual information that is available from study (e.g., response information), the more familiar the word will feel. Indeed, having previously said a word aloud may contribute to participants' success in identifying a studied word as old. Such a strategy would assist recollection of the red words but leave the white words undifferentiated from the new words on the recognition test. In the present case, the encoding of the white words involved no distinctive overt response, and therefore the context at recognition was less informative. The possibility exists that direct tests require greater overlap in all stages of reprocessing from study to test for successful performance. On indirect tests, the earlier stages of processing (e.g., visual scanning of displays, data driven processing) may be of greater importance in enhancing subsequent performance. The latter is consistent with the views mentioned earlier, espoused by Hayman and Tulving (1989), and by Roediger (1990). It is also consistent with the idea of indirect tests relying primarily on recovery of the "initial interpretive encoding" in the Masson and MacLeod (1992) account.

There is one caveat. Participants were instructed to say 'pass' when they encountered white words in the study list. It is possible that the production of this incompatible response may have interfered with further processing of the item. That is, we may have explicitly imposed restrictions on processing by requiring this irrelevant response. To be sure that the present result was not simply due to interference in processing from the 'pass' response, Experiment 2 was conducted. The main goal was to provide an attentional manipulation that did not prevent full processing of white words.

3. Experiment 2

The objective of Experiment 2 was to re-examine the effect of an attentional manipulation at encoding on performance on direct and indirect tests of memory. The result on the direct test of Experiment 1 could simply have been due to impeded encoding of white words because of the irrelevant 'pass' response that was made during study of these items. In the present experiment, participants were instructed to read red words aloud but not to read white words aloud, thereby removing this impediment.

3.1. Method

Participants: Another 20 students from introductory psychology at the University of Toronto at Scarborough participated for bonus credit in their class.

Stimuli, Apparatus, and Procedure: The only change from Experiment 1 was that participants now made no overt response during study to words appearing in white, instead of responding 'pass.'

3.2. Results

Indirect test: The analyses were identical to those conducted in Experiment 1. Table 2 presents the data summary. The ANOVA comparing mean latencies in the rapid reading test as a function of encoding condition (words read aloud at study, words not read aloud at study, and new words) again revealed a significant difference, $F(2,38) = 5.12$, $\mathrm{MSe} = 433.32$, $p < 0.025$. A planned contrast of the mean latencies for new words with the combined mean latencies for studied words was significant, $F(1,19) = 8.22$, $\mathrm{MSe} = 3233.63$, $p < 0.025$, revealing longer latencies for new words relative to the two types of old words. There was about 18 ms of priming – very similar to the 14 ms in Experiment 1 – for words that had appeared in the study

Table 2
Experiment 2: Means and standard errors for correct response times (RT in ms) and error proportions on the rapid reading test, and for d' scores on the recognition test, as a function of encoding condition

Encoding condition	Rapid reading				Recognition	
	RT		Error		d'	
	Mean	SE	Mean	SE	Mean	SE
Read aloud	527	10.44	0.000	0.00	2.24	0.14
Not read aloud	526	11.76	0.000	0.00	0.96	0.10
New	544	13.02	0.000	0.00	–	–

list. The orthogonal contrast of mean latencies for words that were read at study versus those that were not read at study was nonsignificant, $F < 1$, indicating equivalent repetition priming for each type of old word.

Direct test: The one-way ANOVA comparing d' scores was significant, $F(1,19) = 117.42$, $MSe = 0.14$, $p < 0.001$, reflecting more accurate recognition for words read aloud at study than for words not read aloud at study. This finding replicates the direct test finding of Experiment 1.

3.3. Discussion

The results of Experiment 2 are completely in accord with those of Experiment 1. The indirect rapid reading test revealed priming unaffected by attentional manipulations at encoding whereas the direct test showed better recognition for words that had received more attention at encoding than for words that had received less attention. That is, recognition was better for words read aloud than for those not read aloud at study. As suggested earlier, perhaps a stimulus-response coupling at encoding provides greater context, leading to better identification of old items on direct tests. This context might be used to evaluate prior experience, with the participant especially confident of prior study for words that he or she could recollect having spoken during study.

In both Experiments 1 and 2, despite there being no explicit instruction to devote more attention to words that were read aloud compared to words that were not, attention may have been implicitly directed to red words and away from white words. Given that participants were not aware of the subsequent tests of memory, it was an efficient strategy to differentially process words as far as their respective encoding task required. The results of both Experiments 1 and 2 are consistent with the prevalent pattern of differential performance on direct and indirect tests of memory as a result of attentional manipulations at encoding. Based on these findings, direct remembering is highly sensitive to attention at encoding. The goal of Experiment 3 was to address the second question generated by this prevalent pattern of dissociation: Is indirect remembering truly independent of attention at encoding?

4. Experiment 3

The aim of Experiment 3 was again to limit attention to some words at study and to observe how this affected performance on both direct and indirect tests, with the specific goal of altering performance on the indirect test. The intent was to investigate whether indirect remembering could be affected at all by reductions in attention at study or whether encoding for this type of remembering truly occurred automatically without attention to items at encoding (Hayman and Tulving, 1989; Parkin et al., 1990). To test this hypothesis, a dramatic attentional manipulation was required. Therefore, in Experiment 3, the attentional limitation was achieved by presenting two words at the same time and requiring participants to attend to one (the target) and to ignore the other (the distracter). This was explicit in the instructions to participants. Thus, Experiment 3 differed from Experiments 1 and 2 in two fundamental ways: (1) Targets and distracters were presented *simultaneously* at study, and (2) participants were explicitly instructed to attend to targets and to ignore distracters. This selective attention manipulation ensured that even less attention would be allocated to distracter words.

4.1. Method

Participants: Forty students from introductory psychology at the University of Toronto at Scarborough participated for bonus credit in their psychology class.

Stimuli: The stimuli were identical to those used in Experiment 1. In the study phase of Experiment 3, the entire display – the red word, the white word, and the space between them – subtended 1.2° of visual angle when viewed at a distance of 57 cm (the approximate viewing distance in the experiment). Each word, as well as the space separating the words in the display, subtended 0.4° of visual angle when viewed at this distance.

Apparatus: The apparatus was identical to that in Experiment 1.

Procedure: The major change in Experiment 3 was that participants saw two words at a time on each trial during the study phase. The study list now consisted of 40 pairs of words, each pair containing one red word and one white word. Top-bottom position was randomized, with the red word equally likely to be in either position. Half of the participants were instructed to read the word in red and to ignore the word in white; the other half were instructed to read the word in white and to ignore the word in red. The procedure was actually very similar to a negative priming experiment (see, e.g., Fox (1995) for a review) with two differences: (1) In the present study, none of the words were repeated, and (2) participants were not instructed to respond as quickly as they could but rather to read the red words at an average reading pace, as in the two previous experiments. The two words on each trial remained on the screen until the participant spoke a response into the microphone. All other procedures in Experiment 3 were identical to those of Experiment 1.

4.2. Results

Indirect test: Table 3 presents the data summary. A 2 × 3 mixed ANOVA was conducted on the mean latencies from the rapid reading test with color attended at study (red vs. white) as the between-subject factor and encoding condition (attended vs. ignored vs. new) as the within-subject factor. The main effect of color attended was marginally significant, $F(1,38) = 3.64$, $\mathrm{MSe} = 28759.86$, $p = 0.06$, indicating that participants who had attended to the white words in the study phase were faster overall to respond in the rapid reading test relative to those who had attended to the red words in the study phase. The main effect of encoding condition was highly significant, $F(2,76) = 16.86$, $\mathrm{MSe} = 1004.84$, $p < 0.001$. The planned contrast collapsed across color attended, comparing mean latencies for the new words to those for the two types of studied words combined. This was significant, $F(1,39) = 5.99$,

Table 3
Experiment 3: Means and standard errors for correct response times (RT in ms) and error proportions on the rapid reading test, and for d' scores on the recognition test, as a function of encoding condition and group

Encoding condition	Rapid reading				Recognition	
	RT		Error		d'	
	Mean	SE	Mean	SE	Mean	SE
Attended Red						
Attended	573	18.83	0.000	0.00	1.86	0.14
Ignored	618	28.27	0.003	0.00	0.11	0.07
New	610	27.39	0.003	0.00	–	–
Attended White						
Attended	521	18.08	0.000	0.00	1.58	0.18
Ignored	555	19.51	0.003	0.00	−0.03	0.10
New	548	21.57	0.000	0.00	–	–

MSe = 3969.98, $p < 0.020$, revealing longer latencies for new words than for studied words. This result, however, should be viewed in light of the next comparison. The second orthogonal contrast, also collapsed across color attended, compared the mean latencies for the two types of studied words (attended and ignored). This, too, was highly significant, $F(1,39) = 22.74$, MSe = 2631.51, $p < 0.001$. Words that were attended during study produced priming whereas words that were ignored did not.

To complete the picture, an additional post hoc comparison contrasted the mean latencies for words that were ignored with those for new words, collapsed across color attended. This was nonsignificant, $F(1,39) = 1.59$, MSe = 1287.21, $p > 0.20$, confirming that no advantage in reprocessing was conferred on words that were ignored during study; indeed, if anything, there appears to be 7–8 ms of negative priming for the ignored words. In Experiment 3, then, only words that were attended during study were primed on the indirect test. Finally, the Color Attended × Encoding condition interaction was not significant, $F < 1$.

Direct test: A 2 × 2 mixed ANOVA examining recognition d' was conducted with color attended at study (red vs. white) as the between-subject factor and encoding condition (attended vs. ignored) as the within-subject factor. Color attended did not influence performance on the direct test, $F(1,38) = 2.15$, MSe = 0.43, $p > 0.15$. The main effect of encoding condition, however, was highly significant, $F(1,38) = 225.40$, MSe = 0.25, $p < 0.001$, reflecting the fact that words that were attended during study were far better recognized than words that were ignored. In fact, the mean d' score for ignored items reveals no recognition at all on the direct test. The Color Attended × Encoding condition interaction was not significant, $F < 1$.

4.3. Discussion

In Experiment 3, performance was better on both types of tests for the words that were attended during the study phase. The dissociation due to attention at encoding on performance of the direct and indirect tests that was evident in Experiments 1 and 2 disappeared in Experiment 3. In contrast to previous findings of priming for distracters on indirect tests despite reduced attention during study (e.g., Szymanski and MacLeod, 1996), Experiment 3 revealed no priming for distracters. This challenges the prevalent contention that indirect remembering occurs unconstrained by attention at encoding (e.g., Parkin et al., 1990). Not surprisingly, the distracter words were no longer recognized as old items on the direct test when target and distracter words were presented simultaneously in the study phase.

The study phase in Experiment 3 was similar to those used by Phaf (1994) and by Szymanski and MacLeod (1996). The discrepancy in results obtained in the present Experiment 3 and by Szymanski and MacLeod was unexpected. Szymanski and MacLeod manipulated attention in a study phase modelled after the Stroop task (Stroop, 1935). In this case, a color is pitted against a word, where the color is the target and the word is the distracter, quite contrary to the automatic tendency of participants to read the word. Two critical differences distinguish the study phase in the present Experiment 3 from that used by Szymanski and MacLeod. First, Experiment 3 pitted two *words* against each other. Unlike in the Stroop task, where the target color is less salient and presumably less attention-capturing than the distracting word (cf. Melara and Mounts, 1993), both dimensions were equally salient and capable of capturing attention in Experiment 3. In the Stroop task, there is a tendency to orient to words, ensuring some processing of the distracting dimension. In Experiment 3, although at the outset there was an equal probability of orienting to either the red word or the white word, the instruction to attend to the word in one color and to ignore the word in the other color introduced a set that biased attending to the target word. The goal-directed behavior of participants, in the absence of any involuntary stimulus-driven orienting, greatly reduced the probability that the distracter word would be attended. This was indeed the goal of Experiment 3.

The second difference concerns how the two dimensions were displayed in each of these experiments. In the study of Szymanski and MacLeod (1996), the two dimensions (i.e., the attended and the ignored) were perceptually integrated whereas in Experiment 3, because the attended and ignored dimensions were both words, they were spatially separated (for instances in which words were integrated as the attended and ignored dimensions see Milliken et al., in press; MacDonald et al., 1998). The integration versus separation variable is known to affect performance in the Stroop task (cf. MacLeod, in press). Spatial separation normally decreases the Stroop effect, presumably due to decreased attentional capture from the word when it is spatially separated from the color. This is another possible explanation for the discrepant results.

The variables of distracter salience and spatial separation of targets and distracters almost certainly influence performance by altering the amount of attention that the distracter receives. Not replicating the pattern obtained by Szymanski and MacLeod (1996) in no way invalidates either finding: It may simply be the case that the study phase in Experiment 3 provided an instance of a more powerful attentional manipulation.

The principal finding in Experiment 3 is that, like direct remembering, indirect remembering requires attention at encoding. The attentional requirements for successful indirect remembering are simply less demanding than those for successful direct remembering. The present results are not alone in suggesting this (Phaf, 1994 (Experiment 10); Wood and Cowan, 1995). Perhaps Experiment 3 provides a visual analog to the dichotic listening encoding procedure employed by Wood and Cowan (1995). In both cases, there was spatial separation of targets and distracters as well as equally salient material presented as target and distracter information. Both provide instances where attention to distracters is extremely limited, resulting in the absence of remembering for these distracters on both direct and indirect tests.

The study phase in Phaf (1994) (Experiment 10) was also similar to the encoding phase of Experiment 3 in that targets and distracters were equally salient words, presented in spatially separate locations. Despite this similarity, however, Phaf did find some priming on his indirect tests for ignored words whereas no such priming was evident in the present Experiment 3. A significant procedural difference that may account for this discrepancy was that in Phaf's study both words appeared on the screen for 200 ms before the target was signalled. Just due to chance, on some of the encoding trials, the nominally ignored word was likely attended during the 200 ms of uncertainty prior to the cue, thereby mixing actually attended and actually ignored words in the nominally ignored condition. In Experiment 3, by contrast, the print color immediately indicated the target word, providing no reason to examine the ignored word.

One further explanation for the current findings should be considered. Perhaps distracters did not even undergo visual processing. If so, then of course neither direct nor indirect remembering of distracters would be expected. This seems unlikely, however. First, targets and distracters were presented in very close proximity, separated only by a space subtending a visual angle of 0.4°. It seems improbable that participants could completely avoid visually processing distracters while selecting and identifying target words. Keep in mind that targets occurred randomly either in the top or the bottom location so that participants could not predict the target location nor know where to focus their attention at the outset. Because analyses incorporating presentation location as a variable showed that location had no effect, we have not reported these analyses.

In a situation identical to that described in Experiment 3 (i.e., red target words appearing above or below white distracter words), MacDonald et al. (1998) obtained negative priming for previously ignored white words that became red targets on a subsequent trial, confirming that indeed the white words were processed at some level. As well, in an experiment in which the word on each trial was flanked by numbers that participants were asked to sum, Debner and Jacoby (1994) found evidence of unconscious perception and memory on a word fragment completion test occurring immediately after each study trial. Similar to the experience of participants in the present experiment, the authors reported that "The phenomenological experience in this task is often reported as being one of not 'seeing' the flashed word because of attending to the numbers" (p. 310). These examples provide compelling evidence that spatially separated distracters are processed sufficiently to affect immediate subsequent processing, although apparently the attention received by these items is insufficient to support long-term direct or indirect remembering. Finally, Lambert et al. (1988) have shown that semantic information about a word is encoded for distracters presented as far away as 4° from a centrally attended fixation. Given that targets and distracters were separated by a distance subtending only 0.4° of visual angle in the present experiment, the argument that distracters were simply not visually processed seems highly unlikely.

5. General discussion

Not surprisingly, the role that attention plays in memory is complex. The emphasis in the present study was on the influence of attention at the time of encoding on subsequent memory as measured by two predominant categories of memory tests, direct and indirect. Previous work (Eich, 1984; Parkin et al., 1990; Parkin and Russo, 1990; Szymanski and MacLeod, 1996) led to the conclusion that whereas variation in attention at encoding certainly affected performance on direct memory tests, it had little or no influence on indirect tests. The present work helps to paint a more complete picture of this relation.

In Experiments 1 and 2, attentional limitations at encoding indeed did not affect performance on the indirect measure of memory. Equivalent priming occurred for all items in the rapid reading test, regardless of the fact that some items received less attention at encoding. Contrary to the invariance in performance on the indirect test, in both of these experiments, words that received more attention at encoding were better recognized than words that received less attention. The more thorough processing of words that were read aloud at study led to better direct remembering. These finding are very much in line with the expected pattern based on the literature.

Wood and Cowan (1995), however, have argued that prior studies that have manipulated attention at encoding and then observed the effect of this manipulation on subsequent direct and indirect tests have not completely eliminated attention to the nominally unattended information. We concur. Rather, attention has only been reduced. The remaining attention garnered by distracter items is sometimes sufficient to support priming on indirect tests. This was certainly the case in Experiments 1 and 2 where a more subtle attentional manipulation was sought, and was very likely the case in Szymanski and MacLeod (1996) and in Phaf (1994) (Experiment 10). Factors in these experiments ensured that to-be-ignored information in fact received some attention at encoding.

In Experiment 3, the limitation of attention to target words as opposed to distracter words was much more severe. Because the target and distracter words were simultaneously presented, attention was diverted from distracters to targets, the result of actively ignoring the to-be-unattended information. Priming for ignored distracters now disappeared on the indirect test. This suggests that fluency of reprocessing is not enhanced simply because of exposure to, and the resulting visual processing of, a stimulus. It appears that stimuli need to be at least minimally attended and processed at encoding for subsequent indirect remembering to occur. Ignoring the distracter stimulus in favor of processing the target stimulus may have prevented such minimal requirements from being met. It is, of course, to be expected that this harsh limitation of attention favoring targets over distracters resulted in absolutely no recognition of distracters on the direct test. Experiment 3, therefore, provides an instance where the attentional limitation at encoding was serious enough to prevent both direct and indirect remembering. In so doing, Experiment 3 refuted the view that adequate encoding for successful indirect remembering occurs automatically, without attention.

The results of Experiment 3 challenge the notion that indirect remembering occurs for items not attended at encoding. Specifically, these findings appeared to be at odds with the results of Szymanski and MacLeod (1996). However, certain procedural differences exist. In Szymanski and MacLeod, distracters were more salient than targets, and stimuli were presented such that the target and distracter dimensions were integrated. These factors have in fact been implicated in this discrepancy (MacDonald, 1997). It appears that both factors, through their modulation of attention to distracters at encoding, affect participant's success in later indirectly remembering these items.

The aim of the current research was to clarify the relation between attention at encoding and later direct and indirect remembering. Clearly, attention at encoding does matter for both types of tests. Contrary to the notion that automatic sensory registration or data-driven processing is sufficient to facilitate reprocessing on indirect tests (Hayman and Tulving, 1989; Roediger, 1990), the present findings suggest that attention and further processing at the time of encoding are required. Although direct remembering is undeniably more sensitive than indirect remembering to attentional manipulations at encoding, as evidenced by Experiments 1 and 2, minimal attentional requirements for successful indirect remembering also exist. Even slight attentional biasing will impact on subsequent direct remembering whereas indirect remembering can abide much greater reductions in attention at encoding.

It is now clear, however, that when an item receives virtually no attention during encoding, its ability to facilitate later reprocessing is undermined. Previous studies may have failed to reveal this because experimental procedures inadvertently ensured attending to and further processing of nominally unattended or ignored information (Szymanski and MacLeod, 1996; Parkin et al., 1990; Parkin and Russo, 1990). When precautions have been taken to greatly limit focal attention to only some items at study, especially by equating the stimulus-driven attention-capturing properties of both targets and distracters and by presenting these items in a spatially separated manner (i.e., Experiment 3; Phaf, 1994, Experiment 10; Wood and Cowan, 1995), performance is impaired on both direct and indirect tests of remembering.

The interplay between attention and remembering is complicated. Attention at the time of encoding is a necessary component for successful subsequent remembering as measured by both direct and indirect tests. Direct and indirect remembering can no longer be distinguished on the grounds that attentional manipulations affect performance on direct tests but not on indirect tests. In fact, challenges to many of the common memory dissociations (Brown and Mitchell, 1994; Challis and Brodbeck, 1992; Masson and MacLeod, 1992) have recently emerged, undermining broad generalization of these dissociations. Such simple, straightforward characterizations of direct and indirect remembering clearly are not accurate. The present study instead emphasizes the complexity of the relation between attention at encoding and subsequent direct and indirect remembering.

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Appendix A

The 120 words used for study and for the direct and indirect tests in the three experiments are given in the following table.

forest
branch
theatre
amount
judge
answer
shoulder
market
vacation
garden
avenue
engine
pebble
knock
whisper
neighbor
kingdom
arrow
journey
kitchen
pocket
invention
wagon
record
ticket
package
afternoon
capital
clothes
kettle
evening
basket
speech
valley
reward
travel
river
holiday
ladder
orchard
traffic
station
minute
debate
account
quarrel
election
industry
partner
winter
language
treasure
battery
invitation
handle
attention
uncle
fashion
sailor
border
machine
education
factory
furniture
powder
victory
ocean
entrance
merchant
glass
painting
office
thread
guardian
daughter
peace
meadow
turnip
shadow
quarter
leather
history
direction
wheel
uniform
captain
resort
school
foundation
beauty
gravity
plate
distance
attitude
building
harbor
nephew
department
porch
justice
lesson
village
century
address
teacher
trousers
laugh
dinner
stream
queen
friend
campaign
summer
wheat
steam
author
message
island
castle
envelope

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