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Effects of Divided Attention on Encoding and Retrieval Processes in Human Memory: Further Support for an Asymmetry

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Despite a tradition in cognitive psychology that views encoding and retrieval processes in human memory as being similar, F. I. M. Craik, R. Govoni, M. Naveh-Benjamin and N. D. Anderson (1996) have recently shown that notable differences exist between the 2 when divided-attention manipulations are used. In this article, the authors further examined this asymmetry by using several manipulations that changed task demands at encoding and retrieval. The authors also used a secondary-task methodology that allowed a microlevel analysis of the secondary-task costs associated with encoding and retrieval. The results illustrated the resiliency of retrieval processes to manipulations involving different task demands. They also indicated different loci of attention demands at encoding and retrieval. The authors contend that whereas encoding processes are controlled, retrieval processes are obligatory but do require attentional resources for their execution.

Several lines of research on human memory indicate that the processes of encoding and retrieval are similar and that such similarity constitutes one of the prerequisites for successful remembering. These lines of research include the encoding specificity principle (Tulving & Thomson, 1973), transfer-appropriate processing (Morris, Bransford, & Franks, 1977), and the proceduralist view of mind (Kolers, 1973), and all carry the notion of a necessary overlap between encoding and retrieval processes as a precondition for successful remembering. Neuroscientists also echoed this belief by suggesting that the same neural pathways mediate the perceptual processing of stimuli and their storage and recovery (Mishkin & Appenzeller, 1987; Moscovitch, 1992; Squire, 1992). In this sense, memory encoding processes can be conceived as consisting of operations that mediate perceiving and understanding external events, whereas memory retrieval processes are involved in reinstating the same mental–neural operations active at encoding.

There are some results in the literature, however, that are not compatible with this view and that indicate differences between encoding and retrieval processes. One such example is the effects of depressive drugs, which have a detrimental effect on encoding but almost no effect on the retrieval of materials stored in memory (e.g., Birnbaum & Parker, 1977). More relevant to the current research are the results on the effect of divided attention (DA) on encoding and retrieval processes. Use of a dual task paradigm, in which participants' attention is divided between encoding of the information presented and performing a secondary task, was shown to have a clear detrimental effect on memory performance relative to conditions where full attention is paid to encoding the items (e.g., Baddeley, Lewis, Eldridge, & Thomson, 1984; Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; Murdock, 1965). The same effects of DA at encoding were shown for a variety of memory features, including memory for frequency of occurrence (Naveh-Benjamin & Jonides, 1986), memory for spatial location (Naveh-Benjamin, 1987, 1988), and memory for temporal order information (Naveh-Benjamin, 1990). Murdock (1965) found that free-recall performance was higher when memory was emphasized at study, relative to a condition in which card sorting as the secondary task was emphasized. These results indicate that encoding processes require attention and that the allocation of attention to encoding processes is to some extent under the control of the participants.

In contrast, the effects of DA on retrieval processes are quite different. An article by Kellogg, Cocklin, and Bourne (1982) reported only a slight effect of DA at retrieval. Moreover, in six experiments involving free recall, cued recall, and recognition, Baddeley et al. (1984) showed little reduction in episodic memory performance when attention was divided at retrieval. DA had a considerable effect on recognition latency and on latency of retrieval from semantic memory, but very little effect on retrieval accuracy. Baddeley and his collaborators suggested that retrieval

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processes are largely automatic, in contrast with encoding processes, which under DA conditions consistently showed larger memory decrements.

If the retrieval of information is largely automatic, as the above studies indicate, we would expect small effects, if any, of retrieval on secondary task performance. Surprisingly, however, studies that examined the effects of retrieval on secondary task performance (e.g., Johnston, Greenberg, Fisher, & Martin, 1970) found that tracking performance as the secondary task was impaired at retrieval, and to a lesser extent at encoding. Another group of studies, using various secondary tasks (response to auditory targets—Griffith, 1976; concurrent reaction time [RT] to single target stimuli—Johnston, Griffith, & Wagstaff, 1972), showed that retrieval consumes more processing capacity than encoding.

The above results provide paradoxical evidence regarding the nature of retrieval processes. These processes seem to consume an appreciable amount of resources, as indexed by their strong effect on secondary task performance, and yet retrieval performance itself is relatively resistant to the effect of secondary tasks (although retrieval is slowed). The picture for encoding is more straightforward: Division of attention has marked effects on both memory performance and on the secondary task. These qualitative differences between encoding and retrieval are not in line with the earlier-mentioned suggestion that encoding and retrieval processes are qualitatively similar (Craik, 1983; Kolers, 1973).

Recently, Craik et al. (1996) conducted a series of studies intended to unravel the puzzle regarding the differential effects of DA at encoding and at retrieval. In these studies, several methodological shortcomings of previous research were addressed and corrected. One was the use of measures to assess changes simultaneously in memory performance and in concurrent task performance. Previous research typically examined one or the other (e.g., Baddeley et al., 1984; Murdock, 1965). Another problem was the relatively unconstrained nature of the secondary task. For example, concurrent card sorting (Murdock, 1965), holding a string of digits in mind (Baddeley et al., 1984), or the detection of occasional targets (e.g., Griffith, 1976) leaves indeterminate amounts of time and attention to carry out memory related processes. In addition, some concurrent tasks (e.g., card sorting) involve mechanical motor components, allowing participants to use this time to perform more central processing operations required in the memory tasks. A third problem in previous research was the unspecified allocation of resources policy by the participants.

In a series of four experiments, Craik et al. (1996) assessed the similarities and differences between encoding and retrieval processes in human memory by introducing a secondary task either at encoding or at retrieval and comparing its effects on memory, relative to a condition in which both encoding and retrieval were conducted under full attention. The findings were generally in line with previous results, showing that division of attention during the encoding phase of the memory task markedly reduced performance in free recall, cued recall, and recognition memory. Performance on the concurrent RT task slowed down reliably in all cases. Division of attention at retrieval yielded a substantially different picture, in which memory performance was reduced only minimally for free and cued recall, and not at all for recognition. This relative immunity of memory to secondary task interference at retrieval was accompanied by substantial secondary RT costs, which decreased from free recall to cued recall to recognition. In addition, instructions to participants to emphasize either the memory task, the RT task, or both equally, had a marked effect on memory performance under conditions of DA at encoding, but no effect under DA at retrieval. Secondary task RT performance was equally affected by emphasis at encoding and retrieval.

The pattern for DA at encoding yields a straightforward interpretation. Encoding processes are consciously controlled and attention demanding, and therefore division of attention is associated with a reduction in memory performance, along with a slowing of concurrent RT. In addition, changes in emphasis have systematic and complementary effects on both tasks. The effects of DA at retrieval are more complex, however. On the one hand, there was very little effect of DA at retrieval on memory performance. This was accompanied by the lack of effect of emphasis instructions at retrieval. Taken together, these results seem to support Baddeley et al.'s (1984) position that retrieval processes are largely automatic. However, such a position is not compatible with the finding that concurrent RT costs at retrieval were as great or greater than those at encoding. Craik et al. (1996) interpreted these results as indicating that retrieval processes are in some sense obligatory, or are protected, but that their execution requires substantial resources.

The two main purposes of the current series of studies involved the further investigation of the asymmetrical effects of DA on encoding and retrieval processes in human memory. The first purpose concerned memory performance results and the contrast they reveal between the vulnerability of encoding processes and the resilience of retrieval processes to the effects of DA. The second purpose was related to what appears to be, paradoxically, the large secondary task costs associated with this automatic retrieval, costs that are sometimes (under a free-recall task) greater than those associated with encoding.

With respect to the first purpose, we wanted to extend and widen the range of processing demands under which the asymmetry in memory performance is obtained. To this end, in Experiment 1 we used two manipulations that imposed different processing demands that made encoding and retrieval more difficult. So far, studies on the effects of DA at encoding and at retrieval (e.g., Baddeley et al, 1984; Craik et al. 1996) manipulated attention at encoding and at retrieval without changing the processing demands of the memory task. Here, we manipulated several attributes related to the task demands at encoding and retrieval to determine whether, under varied task demands, retrieval operations would still function at an optimal level simultaneously with demanding concurrent activity. For this purpose, we ran a cued-recall experiment in which we manipulated both the availability of the information to be retrieved and the similarity of the perceptual cues at retrieval to those at encoding, and assessed their effects under full or divided attention conditions either at encoding or at retrieval. We measured these effects both on memory performance and on the attentional costs reflected by the concurrent continuous RT task.

For encoding, we expected that division of attention would result in a substantial decrease in later memory performance. With respect to retrieval, if—as previous research indicates—it is obligatory, then even when information that is less available is involved, or when perceptual cues that are less effective are used, the addition of a secondary task should not affect it. Alternatively, under task demands that impose heavy strain, retrieval processes may not be executed at an optimal level when an additional concurrent task is introduced, resulting in a significant decrease in memory performance, as is the case with encoding processes.

With respect to the second purpose of the current studies, concerning the large secondary task costs associated with what seems to be an obligatory retrieval process, our main interest was to learn more about the sources of this demand on resources. To this end, we used a free-recall task because previous research indicates that resource demands at retrieval are especially high under such a task and exceed those at encoding. Furthermore, the results of a free-recall task (Craik et al., 1996, Experiment 1) indicated that certain processes at retrieval (e.g., those associated with actual retrievals) may not be resource demanding. These results showed no change in concurrent RT at retrieval as a function of the number of items retrieved during any particular segment of the retrieval phase in a free-recall task. The results suggest that a significant portion of the retrieval cost in free recall, as indicated by secondary task performance, is not related to processes associated with the retrievals themselves but may be due to other processes (see the General Discussion for details).

However, although the above results by Craik et al. (1996) imply that the extra secondary task cost in free recall is not related to the actual retrieval, the secondary task used by Craik et al. could be methodologically problematic and hence may not warrant such a conclusion. This is so because participants' responses to the secondary task, produced about every 0.5 s, along with the measurement of average RT every 5 s, could have allowed participants to switch between tasks so that even when participants retrieved two or three items per 5-s interval, they could have switched their attention between retrieval and the secondary task, resulting in an apparently fast RT. What is needed is a more sensitive and continuous measurement of secondary task performance that could allow the detection of even momentary changes in performance. Experiment 2 was designed to do exactly that by using a measurement methodology that allowed a microlevel analysis of changes in resources required at encoding and at retrieval for each 5 ms of the task. The aim was to replicate previous free-recall results, and more important, to identify the sources of these extra secondary task costs at retrieval, and to compare them to those associated with encoding.

In both experiments, we used well-established memory paradigms in which encoding and retrieval phases are clearly separated. To avoid modality-specific interference, we presented the verbal information to be remembered auditorily and asked for spoken responses at retrieval, whereas the concurrent tasks used visual stimuli and manual responses. In one experiment, the concurrent task was a continuous four-choice RT task in which the participant's correct response immediately caused the next stimulus to appear. In the other experiment, we used a visual tracking task in which participants had to follow a fast-moving target on the computer monitor with a computer mouse. Because performance on either task performed singly did not reach ceiling, we argue that each task required full attention when performed alone. When performed together, the tasks allowed the assessment of performance throughout the dual task interval.[1]

Experiment 1

In this experiment, we examined the effects of two manipulations of task demands known to affect memory performance under full-attention conditions and assessed their effects on memory performance under DA at encoding and retrieval. One manipulation involved the type of materials to be encoded and retrieved. We compared memory for frequent and infrequent words in a paired-associates paradigm with the purpose of answering two questions: first, whether DA at retrieval would affect memory performance when low frequency words that are less readily available to the retrieval system are used. If low frequency words are harder to recall than high frequency words (Gregg, 1976), we may expect these words not to be readily accessible by the retrieval mechanism and hence to require more search processes that might be interrupted once attention is divided at retrieval. We also wanted to determine whether the

[1] The procedural differences between the two experiments (different secondary tasks, different memory tasks, and single words vs. word pairs) were tailored to the two issues under investigation and did not detract from the theoretical cohesiveness of the package. Specifically, the use of a secondary choice RT task in Experiment 1 enabled us to extend the current results while using the same secondary task used in most relevant studies in the literature. The use of a secondary tracking task in Experiment 2 was mandatory if we were to appropriately investigate the sources of secondary task demands at retrieval. Likewise, the use of cued recall in Experiment 1 allowed us to assess the extension of memory results while ruling out an alternative interpretation—that of different trade-offs between the memory and secondary task performances at encoding and retrieval. As previous research has indicated, using cued recall, which yields similar secondary task demands at encoding and retrieval (as obtained here), eliminates the different trade-off alternative interpretation. In contrast, free recall was the preferable task for the second purpose of the current research (Experiment 2), as in previous research it required ample resources at retrieval, allowing for a better implementation of our microanalysis. Finally, the differences between the experiments in the presentation of word pairs (in Experiment 1) and single words (in Experiment 2) were dictated by the different memory tasks used in the two experiments. Furthermore, the DA literature indicates no particular differences in results when either type of list is used.

retrieval of low frequency words would be associated with a disproportionate increase in secondary task costs.

The second manipulation involved perceptual aspects of the stimuli. This was done by presenting the materials at retrieval either with the same perceptual attributes as at encoding or with different perceptual attributes. Specifically, we manipulated the voice in which the information was presented at retrieval, using the same voice as at study, or a different voice. The literature indicates (e.g., Craik & Kirsner, 1974; Naveh-Benjamin & Craik, 1995) that participants remember information better when the same perceptual information is presented at retrieval, consistent with the encoding specificity principle (Tulving & Thomson, 1973). We wanted to assess the degree to which changing the perceptual attributes of the stimuli at retrieval would hamper cued recall under DA at retrieval, and whether this change would affect secondary task performance.

To allow the assessment of asymmetry between encoding and retrieval, we manipulated word frequency and voice under full attention, DA at encoding, and DA at retrieval.

Method

Participants. The participants were 32 Ben-Gurion University of the Negev undergraduates, who took part in the experiment for course credit.

Design. Three independent variables were used: One was attention—either full attention, DA at encoding, or DA at retrieval; the second variable was frequency in the language of the words presented (frequent vs. infrequent); and the third variable was the voice in which a given item was presented at test (the same as or different from the one presented at encoding). All variables were manipulated within subjects. The dependent variables were proportion of correct cued-recall performance and performance in the secondary continuous four-choice RT (CRT) task.

Stimuli. Words used were two- or three-syllable concrete nouns. Twelve lists were used, with 16 word pairs in each. Six of the lists contained high frequency words (more than 200 per million), and the other six contained low frequency words (less than 30 per million). The words were taken from Hebrew norms (Balgur, 1968). The words in each pair were not related to each other semantically, or in any other obvious way. Half of the pairs in each list (randomly chosen) were presented at study in one female voice and the other half in another female voice. The A–B pairs were presented auditorily at study at a pace of one every 6 s. At test, the A word of each pair was presented as a cue and the participant had to produce the B response within 6 s. Half of the cues were presented in the original voice as at study (either Voice 1 or Voice 2) and the other half in the other voice. The order of words at test was randomized.

The secondary task was the continuous CRT task. It involved a visual display on a computer screen and a manual response on the computer keyboard. The display consisted of four boxes, arranged horizontally. An asterisk appeared at random in one of the boxes, and the participants' task was to press the corresponding key on the keyboard. A correct response caused the asterisk to move immediately to one of the other three boxes at random; the asterisk did not move until the correct key was pressed, and it never appeared in the same box on successive CRT trials.

Procedure. Each participant was presented with the 12 lists, which were two replications of all combinations of three attention conditions and the two frequency levels. In addition, each participant performed the CRT baseline task four times, each for 96 s (which was the length of both the encoding and retrieval phases). The assignment of lists to the different attention conditions was counterbalanced so that across subjects each list served in each of the attention conditions the same number of times. Twelve formats of order were created in which the order of the 12 memory trials was counterbalanced using a Latin square design. Three participants were tested in 8 of these formats, and 2 participants were tested in the remaining 4 formats. The CRT baseline task was done before the 1st list, and after the 4th, the 8th, and the 12th list.

Before the experimental trials began, each participant received a short practice session with each of the attention conditions and with the CRT task. In the full attention trials, participants were told to pay attention to the words in order to encode and retrieve them as best they could. In the secondary baseline CRT trials, participants were told to respond as quickly as they could while avoiding errors. Finally, in the DA trials, participants were told to split their attention between the CRT task and the encoding or retrieval of the words. The experimental lists were then presented one at a time, with the encoding and the retrieval phases taking 96 s each (16 pairs or cues × 6 s each). After the encoding phase, participants performed an interpolated activity for 30 s (counting backwards in sevens from a predesignated number, which was different for each list). Before each list, participants were told which attention condition to expect but were not told about the frequency manipulation.

Results

Memory performance. Figure 1A presents the percentage of words recalled as a function of attention condition, frequency of the words, and voice at test (means and standard deviations for the experiments reported in this article appear in Table 1). A three-way analysis of variance (ANOVA) indicated a significant effect of attention, $F(2, 62) = 56.83$, $p < .01$, $MSE = 269.8$. Follow-up analyses indicated that the source of this effect was the poorer performance of participants under DA at encoding ($M = 31.6\%$) relative to the full attention condition ($M = 51.9\%$), $F(1, 31) = 80.39$, $p < .01$, $MSE = 322.2$. There were no significant differences between DA at retrieval ($M = 49.4\%$) and full attention ($M = 51.9\%$), $F(1, 31) = 1.99$, *ns*, $MSE = 214.4$. The ANOVA also indicated a significant effect of word frequency, $F(1, 31) = 79.81$, $p < .01$, $MSE = 231.3$, showing that high frequency words ($M = 51.3\%$) were better remembered than low frequency words ($M = 37.5\%$). Finally, the ANOVA also indicated a significant effect of voice, $F(1, 31) = 26.90$, $p < .01$, $MSE = 96.8$, in which the same voice condition ($M = 47.0\%$) resulted in better memory performance than the different voice condition ($M = 41.6\%$). None of the interactions were significant.

CRT secondary task. Figure 1B presents mean RTs as a function of attention (DA at encoding vs. DA at retrieval), frequency of words, and voice at test. A three-way ANOVA (with only two levels of attention: DA at encoding and at retrieval) indicated only a significant effect of frequency, $F(1, 31) = 7.72$, $p < .01$, $MSE = 3{,}283.6$, showing that RT for high frequency words (526 ms) was faster than that for low frequency words (547 ms). There was no significant

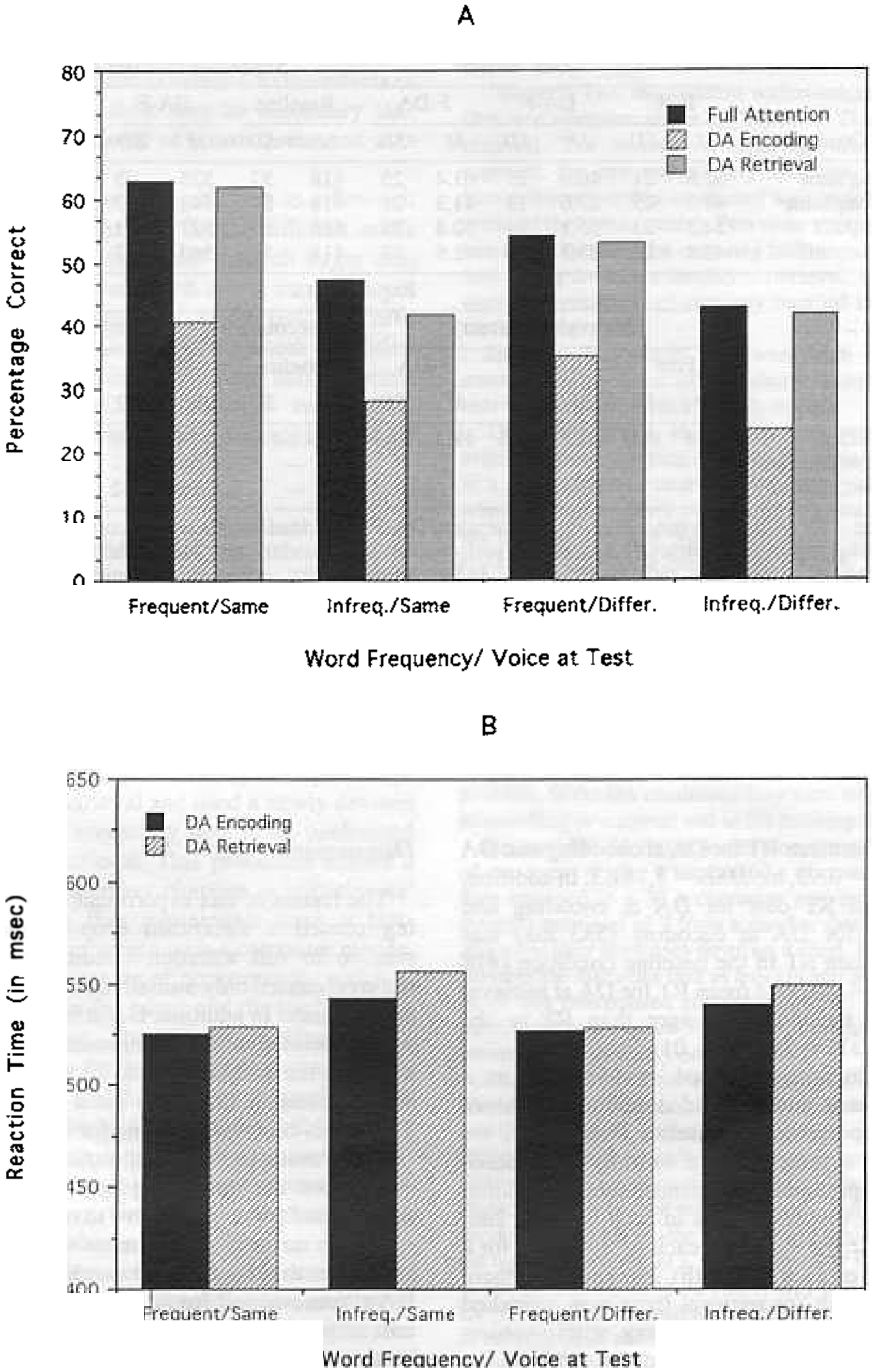

Figure 1. A: Percentage of words correctly recalled (cued recall) in the different combinations of word frequency (frequent vs. infrequent [Infreq.]) and voice at test (same vs. different [Differ.]), under conditions of full attention (Full Attention), divided attention at encoding (DA Encoding), and divided attention at retrieval (DA Retrieval) in Experiment 1. B: Performance on the continuous secondary choice reaction time task in the different combinations of word frequency (frequent vs. infrequent [Infreq.]) and voice at test (same vs. different [Differ.]), under conditions of divided attention at encoding (DA Encoding) and divided attention at retrieval (DA Retrieval) in Experiment 1.

Table 1
Means and Standard Deviations for the Different Conditions of the Two Experiments

Experiment 1

	Memory (% correct)						Secondary task (RT in ms)					
	Free		DA-F		F-DA		Baseline		DA-F		F-DA	
Condition	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Freq/same	62.8	21	40.6	23	61.4	25	418	57				
Infreq/same	47.3	25	27.6	18	41.3	21	418	57				
Freq/diff	54.3	23	35.1	24	52.8	25	418	57				
Infreq/diff	42.8	26	23.3	19	41.6	22	418	57				

Experiment 2

	Memory (% correct)						Secondary task (distance in mm)[a]					
	Free		DA-F		F-DA		Baseline		DA-F		F-DA	
	M	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
Overall[b]	50.9	14.8	42.7	19.5	49.2	12.9	23.9	4.41	0.76	1.39	2.58	3.05
Between events	—		—		—			—	0.59	1.37	2.53	3.04
Event related	—		—		—			—	0.68	1.32	0.18	2.20

Note. RT = reaction time; Free = full attention; DA-F = divided attention at encoding; F-DA = divided attention at retrieval; Baseline = performance on secondary task alone; Freq = frequent; Infreq = infrequent; diff = different. [a]After adjusting for orienting response and motor conflict. [b]The overall tracking performance is based on the entire duration of the encoding and retrieval periods. For encoding, about one quarter of the overall tracking cost (1 s of the 4 s allocated for each word) is associated with the event-related period, and about three quarters of the tracking cost (the remaining 3 s of 4 s allocated for each word) is associated with the between-events period. Likewise, for retrieval, about one quarter of the tracking cost (7.5 s of the total 30 s allocated for retrieval, based on 1 s associated with the retrieval of each of the 7.5 words retrieved on average) is associated with the event-related period, and about three quarters of the tracking cost (the remaining 22.5 s) is associated with the between-events period.

difference between the mean RT for DA at encoding and DA at retrieval, $F(1, 31) = 0.93$, *ns*, $MSE = 3{,}141.3$. In addition, there was an overall RT cost for DA at encoding and retrieval. Mean RT for DA at encoding (533 ms) was significantly longer than RT in the baseline condition (418 ms), $t(31) = 5.42$, $p < .01$, and mean RT for DA at retrieval (540 ms) was also significantly longer than RT in the baseline condition, $t(31) = 5.27$, $p < .01$.

We also looked at secondary task performance as a function of word order at encoding and at retrieval. To do so, we subtracted the appropriate RT baseline from the RT for DA at encoding and at retrieval on a word-by-word basis. We sampled for each participant segments either at encoding or at retrieval for the first few words in each list (1st, 2nd, 3rd, 4th), for a word in the middle of each list (8th) and for a word toward the end of each list (15th). For encoding there was no clear pattern, but for retrieval there was a marked higher cost for the first word. A one-way within-subject ANOVA with word position (1st, 2nd, 3rd, 8th, 15th) as the variable indicated no effect of word order at encoding on secondary task RT, $F(5, 155) < 1$. Another one-way within-subject ANOVA indicated a significant effect of word order at retrieval on secondary task RT, $F(5, 155) = 40.73$, $p < .01$, $MSE = 6{,}573.9$. Post hoc comparisons using the Newman–Keuls procedure indicated that the only significant differences were those between the first retrieved word ($M = 300$ ms RT cost) and the other words ($M = 110$ ms RT cost; all $ps < .05$).

Discussion

The results of this experiment showed that DA at encoding caused a significant drop in memory performance relative to full attention conditions. In contrast, DA at retrieval caused only a small, nonsignificant drop in memory performance. In addition, DA at both encoding and retrieval was associated with a significant attentional cost, as measured by the secondary task. In this experiment, as in past experimentation that used cued recall (e.g., Craik et al., 1996), this cost was the same for encoding and retrieval.

Such results indicate that retrieval is not sensitive to DA, even when the processing task demands are made more difficult and participants have to recall low frequency words. Although memory performance was significantly lower for infrequent than for frequent words, this effect was similar for DA at retrieval and for full attention. There was, however, a cost associated with retrieving infrequent words as indicated by the secondary task performance, which was larger than the cost associated with the retrieval of frequent words. In general, it seems that although retrieval is immune to the effects of DA (because low frequency words show the same level of recall under DA at retrieval as under full attention), this immunity is associated with some cost (requiring resources), as reflected in secondary task performance.

Similar results emerged for the manipulation of the perceptual properties of the stimuli. Retrieval appeared to be insensitive to DA, even when there was a change in the voice in which the retrieval cue was presented. Memory performance was significantly higher for same-voice than for different-voice words, but this effect was of the same magnitude under DA at retrieval as under full attention conditions. In this case, however, in contrast to the effects of frequency mentioned above, there was no secondary task cost associated with the retrieval of words presented in a different voice.

Finally, analyses of the secondary task cost as a function of word order revealed no differences for the different words at encoding. However, they did reveal a much larger cost associated with the first retrieved word, a cost that surpasses slowing that is due to "getting used to the task" because results were adjusted to baseline secondary task condition performance. This cost associated with the first retrieved word may reflect the attentional resources required in initiating and entering a retrieval mode (Tulving, 1983, see the General Discussion).

Experiment 2

As we have noted, the purpose of Experiment 2 was to assess secondary task costs associated with what seems to be obligatory retrieval processes, costs that are sometimes greater than those associated with encoding. Specifically, we wished to localize these costs during both the encoding and the retrieval periods. To this end, we used a free-recall task previously shown (e.g., Craik et al., 1996) to impose high demands for resources at retrieval and used a newly devised tracking procedure as the secondary task to be performed along with encoding or retrieval. This procedure allows a microlevel analysis of momentary changes in participants' performance by requiring that participants track a fast-moving target on a computer screen with a computer mouse. The program provides a measure of performance, which is the spatial distance between the target and the tracker every 5 ms in a continuous fashion. The exact times when stimuli are presented auditorily by the experimenter during encoding and when participants' vocal responses are made during retrieval are recorded by the computer through the use of a voice-operated relay and are superimposed on the continuous distance measure. This enables the measurement of the tracking task performance at virtually any moment during the encoding and retrieval phases.

After subtracting the effects of orienting response to the presented words at encoding, and those of motor conflict at retrieval (obtained in control conditions), we split the encoding and the retrieval periods into two main subcomponents: those associated with the specific encoding or retrieval of "events" (the short interval before, during, and after each encoding or retrieval) and those associated with the rest of the encoding or retrieval period (the intervals "between the events," encoding or retrieval of a word). We examined memory performance as well as the secondary tracking task performance to confirm that in this different paradigm the previously obtained differential memory effects of DA at encoding and retrieval are also found.

Method

Participants. The participants were 27 Ben-Gurion University of the Negev undergraduates, who took part in the experiment for course credit.

Design. Two independent within-subject variables were used. One was attention: either full attention, DA at encoding, or DA at retrieval. The second variable was the encoding or retrieval segment: the one immediately surrounding the encoding or retrieval (event), or that associated with periods between encoding or retrieval (between events). Two more control conditions were used, one for controlling the orienting task at encoding and the other for controlling the motor conflict at retrieval. The dependent variables were the proportion of correctly recalled targets and performance on the tracking task.

Stimuli. The words used were high frequency two-syllable concrete nouns taken from Hebrew norms (Balgur, 1968). Nine lists were created, with 15 words in each.

The tracking task involved a computer screen on which an asterisk moved at a pace of 6 cm per second. This pace was chosen in a pilot study as one that is moderately difficult for participants when used alone (their performance indicated no ceiling effect, as the distance measure was significantly higher than 0 mm). Four tracking paths were designated, which were combinations of left–right and up–down directions. Although the movement of the asterisk appeared to be random, it had been predesignated for each path. Participants followed the asterisk with the computer mouse, which controlled a plus sign indicating their position on the screen.

Procedure. Under the full attention condition participants were told to pay full attention to the lists in order to encode and retrieve them. In the tracking baseline condition, participants were instructed to catch the asterisk target or to follow it as closely as possible. In the DA conditions they were told to pay equal attention to encoding or retrieval and to the tracking task.

For each list, 15 single words were presented auditorily at a pace of one every 4 s for a total of 60 s of encoding. Participants were then engaged in a 30 s distractor activity, in which they had to subtract multiples of 7 from a number that appeared on the screen and write their responses down on a sheet. Participants were told to perform the distractor task as quickly and as accurately as possible. After this interpolated activity, the recall phase began, in which participants were given 30 s to recall as many as possible of the 15 presented words in any order.

There were six experimental tasks: (a) The first task assessed single-task performance involving memory full attention (three trials). In this task, participants received instructions to encode and retrieve information under full attention conditions. (b) The second task assessed single-task performance in tracking (eight trials). Participants performed only the tracking task. On four trials, which served as control for the encoding phase, participants performed the tracking task for 60 s, and on the other four trials, which served as control for the retrieval phase, they performed the tracking task for 30 s. Each of the four trials at encoding and at retrieval used one of the four basic paths from each of the memory trials. Participants' reports after the experiment indicated that they did not realize that the same four paths were repeated, but perceived the movement of the asterisk as random. (c) The third task assessed dual-task performance in terms of DA at encoding (three trials). On these trials, participants performed the encoding and the tracking task simultaneously, under instructions to pay equal attention to each; retrieval was done under full attention. We used three of the four predesignated paths, one for each trial. (d) The fourth task assesses dual-task performance in terms of DA at retrieval (three trials). On each of these trials, participants encoded information under full attention and then performed the retrieval and the tracking task simultaneously, under instructions to pay equal attention to each. Again, three of the four predesignated paths were used, one for each trial. (e) The fifth task assessed dual task performance and involved control for the orienting response at encoding (two trials). Any change in tracking task performance during encoding associated with the appearance of words could be related either to the intentional processing of the words (as was intended) or to the fact that a stimulus appeared, which resulted in an orienting attentional response. In this condition, we assessed the tracking task cost associated with such orienting responses by presenting a nonword auditorily every 4 s to participants who performed the tracking task for 60 s. Participants were instructed to ignore the auditory stimuli. (f) The sixth task assessed dual-task performance and involved control for motor-output conflict at retrieval (two trials). Any change in the tracking performance during the time when participants were retrieving a word could be related either to the attentional resources required for the retrieval of the event (as intended) or to structural–motor interference caused by participants having to control their motor tracking while also saying aloud the retrieved word. To control for the motor-conflict component, participants had to perform the tracking task simultaneously with other motor activity for 30 s. The motor activity involved saying aloud a predesignated word each time a tone was sounded. The computer was programmed to beep at intervals corresponding to the average pattern of retrieved responses by participants during a DA recall trial in a pilot study. The tone sounded either eight or nine times, with greater frequency at the beginning of the 30-s interval, to mimic the typical temporal distribution of recall. The participant's task was to concentrate on the tracking task, but also to say the same predesignated two-syllable noun each time the tone sounded. Such a task is identical in all aspects to the DA at retrieval task, but it does not require long-term episodic retrieval.

The presentation of each word at encoding (via the tape recorder) and participants' vocal retrieval of each word triggered the voice-operated relay that recorded the exact time when such an event was initiated.

Participants initially practiced the tracking task alone, the memory task alone (full attention), and their combination either at encoding (DA at encoding) or at retrieval (DA at retrieval). Participants also practiced each of the two control conditions (Tasks e and f). They then continued with the experimental trials. Nine formats of order of tasks were used in which the order of the nine memory trials (three for each attention condition) was counterbalanced using a Latin square design, and 3 participants were tested in each order. The eight single tracking task trials were scattered in between the nine memory trials. The two trials controlling for motor-output conflict and the two controlling for orienting response were run one at the beginning and one at the end of the experimental trials. Each word list was used across subjects an equal number of times in each of the attention conditions.

Results

Memory performance. The following data presented are for 26 of the participants. One participant was excluded because of a misunderstanding of the instructions. The mean percentage of words recalled was 50.9% (SD = 14.8) in the full attention condition, 42.7% (SD = 19.5) in the DA at encoding condition, and 49.2% (SD = 12.9) in the DA at retrieval condition. A one-way ANOVA showed a significant effect of attention, $F(2, 54) = 9.43$, $p < .01$, $MSE = 1.2$. A comparison of full attention and DA at encoding showed a significant difference ($p < .05$), but a comparison of full attention and DA at retrieval showed none. The comparison of DA at encoding and DA at retrieval was significant ($p < .05$). These results replicate those obtained in Experiment 1 reported above, and in Experiments 1 and 2 in the Craik et al. (1996) study that utilized free recall: DA at encoding resulted in a much larger decrease in memory performance than did DA at retrieval.

Tracking task performance. For each condition, we averaged the distance (in millimeters) between the target and the tracker after each 5-ms interval, over the whole trial. To provide a more precise measurement of encoding and retrieval DA costs, we subtracted the appropriate baseline distance for each trial. We did this by slicing both the DA condition and its paired control condition (which used the same spatial path) into 20-ms segments (averaging over four distance intervals of 5 ms each) and subtracting the tracking distance performance on the single task from its appropriate list condition (the one that used the exact same path). This assured a precise cost associated with the encoding or retrieval tasks every 20 ms, when target paths are kept constant. The resultant overall tracking distance was larger at retrieval (2.55 mm) than at encoding (1.88 mm), thereby mimicking the effects found in Experiments 1 and 2 of Craik et al. (1996), who used a similar free-recall task.

The resultant distance was then divided into segments of "before," "after," and "between" intervals. We pretested several segment lengths at encoding and at retrieval ranging from 100 to 1,000 ms, and the results were fairly similar. In addition, after 1,000 ms there was a marked drop in tracking cost at encoding, indicating that a significant part of the encoding activity for a given word had been completed by then. Consequently, we decided on a middle range value of 500 ms per segment, where it is reasonable to believe that specific encoding activity occurs. We therefore defined the "before" segments for encoding as those associated with 500 ms prior to the presentation of each word at encoding, and the "after" segments at encoding as those associated with 500 ms after a presentation of a word. The "between" segments were defined as those associated with a 500-ms interval at the midpoint between two presentations of words, that is, from 1.75 till 2.25 s after the presentation of each word. (For these "between" segments we initially used either 500 ms at the midpoint as described above, or the full range between two consecutive encodings or retrievals. Because the results were similar, we chose the midpoint, which is equal in duration, 500 ms, to the two other segments.)

For retrieval, we used the same partition, where "before" segments were associated with 500 ms prior to a given retrieval (as indicated by the activation of the voice-operated relay) because covert retrieval activity may occur prior to the overt response, "after" segments were those associated with 500 ms after the initiation of a given overt retrieval (500 ms since the onset of the voice-operated relay), and "between" segments were those associated with 500 ms at the midpoint between two retrievals. Because in no case were consecutive retrievals less than 1,000 ms apart, there was a "between" segment for every two consecutive words, which occurred after a given retrieval and likely before the initiation of the next one. In a few cases (less than 10%), when words were retrieved less than 1,500 ms apart, the "between" segment was less than 500 ms. Figure 2 presents timeline diagrams that illustrate the sequence of events that occurred during the different tasks.

Next, we separated the effects associated with the periods between encodings and retrievals from those immediately surrounding encoding and retrieval events (event-related). To obtain estimates for the encoding or retrieval periods between events, we computed the average difference in the distance tracking task measure between the "between" segments and the appropriate baseline (single-task) segments. This reflects the attentional cost associated with periods between the encoding and retrieval of specific items when no actual encoding or retrieval is performed. To obtain estimates for event-related (either encoding or retrieval) secondary task cost that surpasses that of between events, we computed the mean average differences between the "before" and "after" portions and the "between" portions. This reflects the cost associated with specific encoding or retrieval above and beyond that associated with periods between encoding or retrieval. Figure 3A presents the results for associated costs for these two components at encoding and at retrieval.

To control for the effects of orienting response at encoding and motor conflict at retrieval, we subtracted the tracking task performance under orienting response and motor-conflict trials from tracking performance under DA trials at encoding and retrieval, respectively. We subtracted these values for the "event" portions only because these are the ones associated with the specific encodings or retrievals (they happen only 500 ms prior to and after an event), and not the other periods between encodings or retrievals. Figure 3B presents the corrected results.[2]

A two-way ANOVA on these corrected results, involving stage (encoding vs. retrieval) and period (between events vs. event-related), indicated a significant effect of stage, $F(1, 25) = 7.07$, $p < .05$, $MSE = 1.9$, where retrieval required more resources than encoding, and a significant effect of period, $F(1, 25) = 4.76$, $p < .05$, $MSE = 7.0$, which indicates that the cost associated with periods between events was greater than the extra cost associated with event-related periods. More interesting, the interaction of the two variables was significant, $F(1, 25) = 4.88$, $p < .05$, $MSE = 7.9$. Follow-up specific comparisons indicated that although between-events costs were larger at retrieval than at encoding, $F(1, 25) = 9.51$, $p < .05$, $MSE = 5.1$, event-related costs were not different between the two ($F < 1$, *ns*). Moreover, although the event-related cost (0.68) was significantly larger than 0.0 at encoding, $t(25) = 2.73$, $p < .05$, its cost at retrieval (0.18) was not significantly different from 0.0, $t(25) = 0.37$, *ns*, partially as a result of the much larger tracking performance variability at retrieval than at encoding.[3]

Discussion

Use of careful measurement procedures allowed the separation of attentional costs associated with periods between the encoding and retrieval of events from those associated with specific events at encoding and at retrieval. The results provide a replication of previous studies (Craik et al., 1996) and of those obtained in Experiment 1 above, indicating large memory costs for divided attention at encoding but not at retrieval. More important, these results show that the larger secondary task costs associated with free-recall retrieval than with encoding may be related to the periods between the retrievals of specific items, with apparently little cost for each specific retrieval. Encoding, on the other hand, has been shown to require resources both for periods between encodings (though smaller than the cost required for comparable periods during retrieval) and for event-specific encoding processes.

General Discussion

To summarize our major findings, we have found that whereas division of attention at encoding reduces memory performance markedly, division of attention at retrieval has almost no effect on memory performance. Experiment 1 demonstrated that this is the case even when the task's processing demands are made more difficult by making the items less available, or by changing their perceptual characteristics from encoding to retrieval. Despite the fact that these manipulations adversely affected general memory

[2] Because of a procedural oversight, only 16 out of the 26 participants performed the control tasks for orienting response and motor conflict. The mean estimates of these components for these participants were computed and then applied to the other participants' results.

[3] As pointed out to us by Neil Mulligan, the control for motor-output conflict task (Task f), which was supposed to control for speech output, might also have required participants to monitor the external environment for the output signal (the beep), and as such, might consequently have inflated the effect of motor output. This could consequently increase the differences at retrieval between the "event-related" segment and that associated with the "between events" segment. The monitoring of the external environment component in Task f, however, is probably minimal as it is similar to the processes required in Task e (dual-task performance involving monitoring for orienting response), whose secondary task costs were negligible (see differences between Figure 3A and 3B in the event-related component at encoding). To take a conservative approach, we nevertheless conducted an ANOVA on the data presented in Figure 3A, which did not control for motor-output conflict. The ANOVA indicated trends similar to those obtained with the data of Figure 3B, as there was a significant effect of stage, $F(1, 25) = 16.58$, $p < .05$, $MSE = 1.5$, where retrieval required more resources than encoding, and no significant effect of period, $F(1, 25) = 2.18$, *ns*, $MSE = 7.9$. The interaction of the two was marginally significant, $F(1, 25) = 3.43$, $p < .10$, $MSE = 7.3$. Follow-up specific comparisons indicated that although between-events costs were larger at retrieval than at encoding, $F(1, 25) = 9.51$, $p < .05$, $MSE = 5.1$, costs associated with the event were not different between the two ($F < 1$, *ns*). Moreover, although the cost of the event (0.78) was significantly larger than 0.0 at encoding, $t(25) = 3.17$, $p < .05$, the cost at retrieval (0.74) was not significantly different from 0.0, $t(25) = 1.58$, *ns*, partially because of the much larger tracking performance variability at retrieval than at encoding.

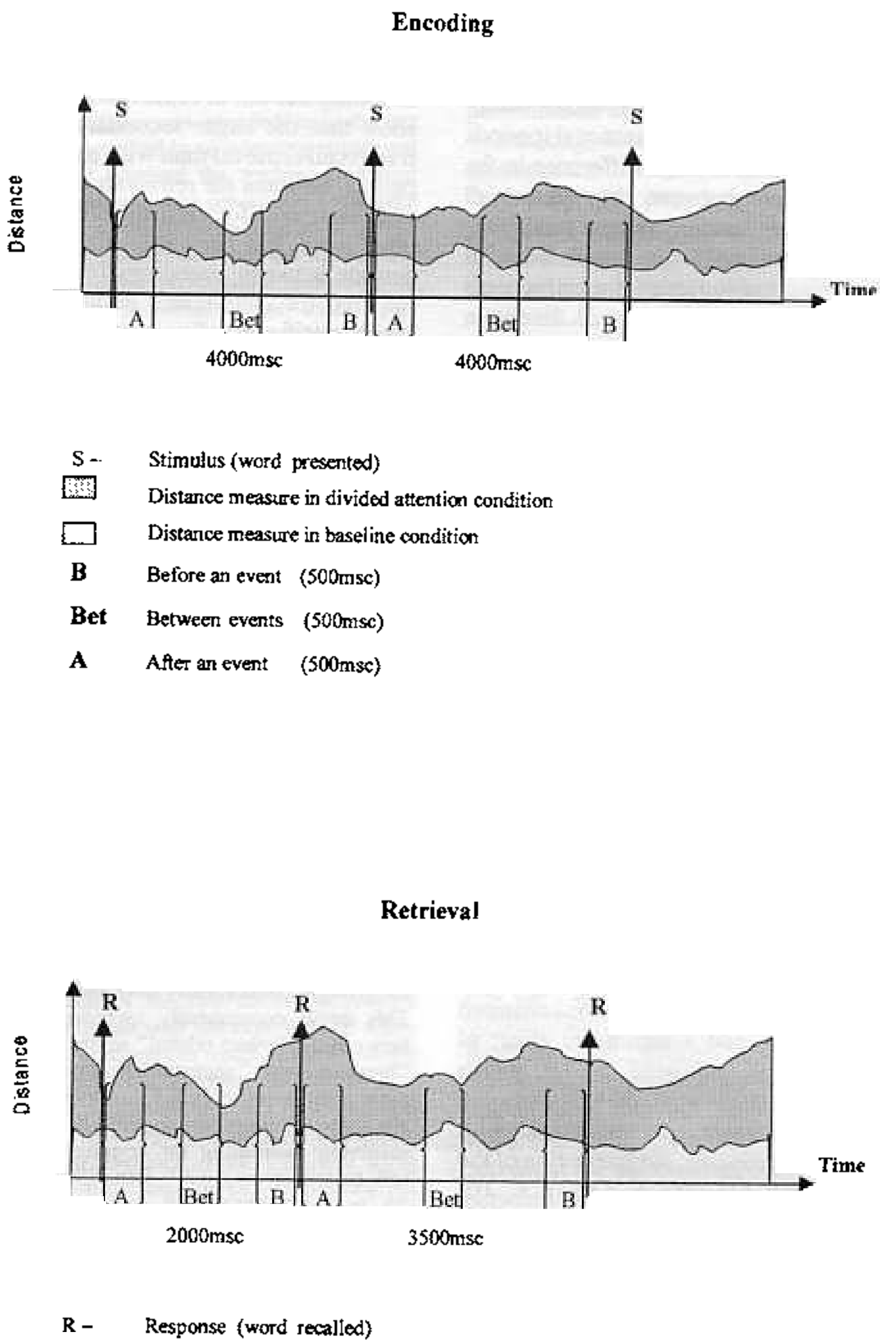

Figure 2. Time line diagrams illustrating three events in the series that occurred during encoding and retrieval. Event was either a stimulus word that occurred at 4,000-ms intervals during encoding, and at varied intervals, depending on participants' actual recall response, during retrieval. No events occurred in the baseline conditions. The between-event component is based on the average of 500-ms segments between events where baseline distance performance for these segments was subtracted from the distance measure either at encoding or at retrieval. The event-related component was based on the average distance performance for the B (before) and A (after) segments after the baseline and between-events distance measures were subtracted. Results presented in the text are based on averaging distances across these segments for all words either at encoding or at retrieval.

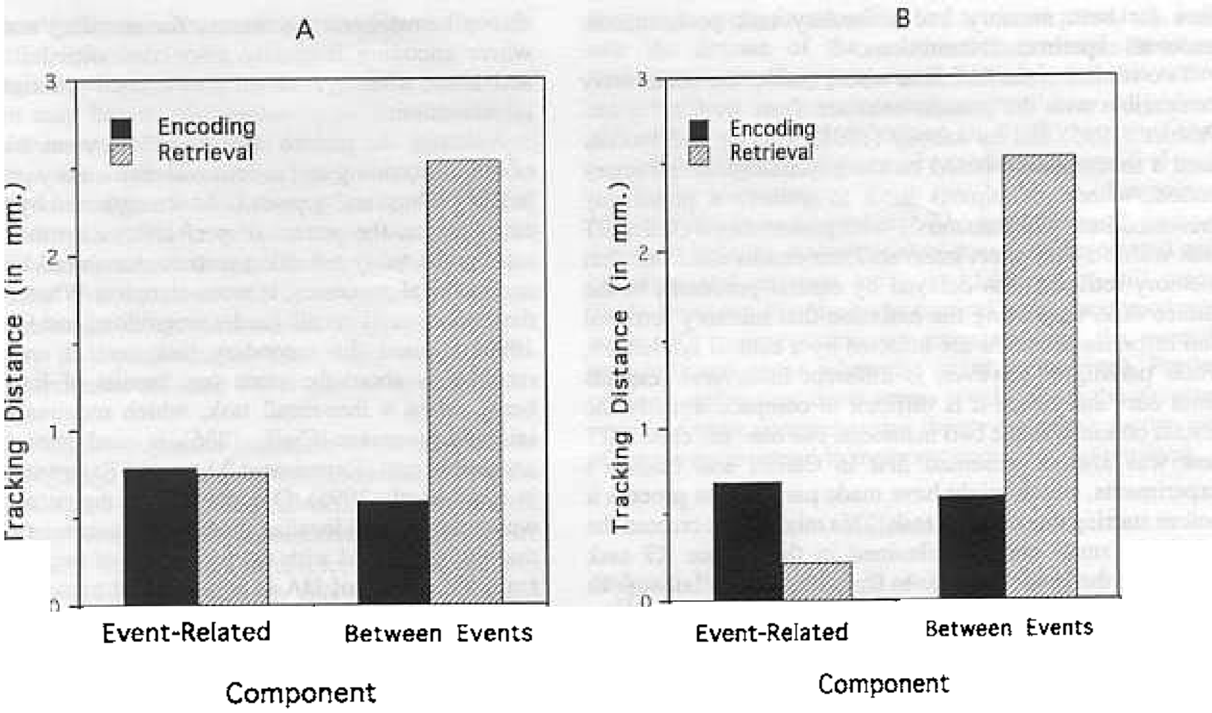

Figure 3. A: Performance on the tracking task during the event-related and between-events segments for encoding and retrieval in Experiment 2. B: Performance on the tracking task during the event-related and between-events segments for encoding and retrieval after controlling orienting response at encoding and motor conflict at retrieval in Experiment 2.

performance, retrieval was protected under divided attention. Experiment 2 showed the same pattern even when a free-recall retrieval task was used.

Is it possible that the observed asymmetry between the effects of DA at encoding and at retrieval on memory performance stems, at least in part, from different trade-off strategies adopted by participants at encoding and retrieval? Participants may have given priority to the RT task at encoding, and to the memory task at retrieval. Also, the consequences of paying more or less attention to encoding operations are not felt until a later time, as opposed to the immediate feedback for success or failure at retrieval. In the same vein, it has been shown that experimental participants are not very sensitive to the effects of different types of encoding operations on later memory performance (Shaw & Craik, 1989), so participants in a dual-task situation may allocate less attention than is necessary for proper encoding.

We believe that the asymmetry reflects fundamental differences between encoding and retrieval, rather than a simple difference in attentional allocation policy. First, in Experiment 1 above, as well as in Experiments 2–4 in Craik et al. (1996), all of which used cued-recall or recognition memory tasks, the concurrent task costs are the same at encoding and retrieval, yet divided attention at encoding has a much greater effect on performance. Second, in Experiments 2–4 in Craik et al. (1996), manipulation of emphasis on the two tasks changed secondary task performance without having any effect whatsoever on retrieval performance (Craik et al., 1996); that is, shifting participants' priorities from retrieval to the secondary task improved performance in the secondary task but had no effect on memory performance under DA at retrieval. When manipulated at encoding, such a shift in emphasis reduced memory performance under DA even further. The same pattern—that of shifting priorities at retrieval having no effect—was recently obtained by Anderson, Craik, and Naveh-Benjamin (in press) for both young people (Experiment 2) and older adults (Experiment 4).

The different patterns of memory performance under DA at encoding and retrieval are also unrelated to the differential degrees of control that participants have during these two phases. One difference between encoding and retrieval is that whereas the presentation of stimuli at encoding is under the experimenter's control, the retrieval of information is under the control of the participant; that is, the participant can decide when to deploy retrieval operations, and may do this at times that optimize retrieval performance. Such flexibility is much more constrained at encoding, where the timing of stimulus presentation is determined by the experimenter. This argument is weaker for cued recall and recognition than it is for free recall, because retrieval cues are also presented by the experimenter in the first two cases. However, we ran several studies that further minimize this possibility (Craik, Naveh-Benjamin, & Anderson, 1998). In one of these experiments, the appearance of the stimuli during encoding and of the cues during retrieval was controlled either by the participants or by the experimenter. Yet the results indicated the exact same patterns reported here for both memory and secondary task performance, under all experimental conditions.

Two studies in the literature whose results are not entirely compatible with the present ones are those by Carrier and Pashler (1995) and by Jacoby (1991). Carrier and Pashler used a methodology based on the psychological refractory period, where participants have to retrieve a previously presented item simultaneously with performing a choice RT task within a very short interval. Their results indicated that memory retrieval was delayed by central processes in the choice task, supporting the assertion that memory retrieval and response selection are affected by a central bottleneck. Their paradigm, however, is different in several respects from ours and hence it is difficult to compare directly the results obtained in the two instances. For one, the choice RT task was always presented first in Carrier and Pashler's experiments, which might have made participants process it before starting the retrieval task. This might have created the relatively small changes obtained in the choice RT task relative to the larger changes in the retrieval task latency. To increase the credibility of these results, they should be replicated with the retrieval task presented first. Furthermore, because retrieval latency was the major variable measured, we have no information regarding the effects of this presumed bottleneck on memory performance, as no retrieval baseline condition was used in their study.

To accommodate the different patterns of results, Carrier and Pashler (1995) suggested that the results obtained by Baddeley et al. (1984), indicating no affect of secondary task at retrieval on memory performance, may be due to a ceiling effect in memory performance. This was clearly not the case in the experiments reported in the present article, where single-task performance was around 60%. Carrier and Pashler also noted that participants in Baddeley et al.'s study could have switched tasks rapidly, allowing them to protect retrieval performance under division of attention. This is unlikely in our experiments because, as mentioned above, we intentionally used continuous secondary tasks that required participants' constant attention. In addition, in another study (Craik et al., 1998), retrieval performance was protected under DA even under conditions where participants had very short time slots of less than 1.5 s to retrieve the information.

Jacoby (1991) showed that memory performance is reduced under DA at retrieval especially when deep operations (anagram solution) were performed at study. His study, however, used complex and multifaceted retrieval decisions that involved both item recognition memory and source memory performed in a very limited time. Under such conditions, unlike those used by us, which involve the more simple and traditional memory tasks (free and cued recall), memory performance may suffer under DA at retrieval.

The results reported in the present article, indicating different performance patterns at encoding and retrieval, are compatible with recent studies using brain imaging techniques, which allow researchers to examine the brain correlates of encoding and retrieval processes separately. These studies (e.g., Tulving, Kapur, Craik, Moscovitch, & Houle, 1994, who used positron emission tomography) have shown hemispheric asymmetry for encoding and retrieval, where encoding is mostly associated with left prefrontal activation, whereas retrieval is associated with right prefrontal activation.

Although the picture regarding the asymmetrical effects of DA at encoding and at retrieval on memory performance is fairly robust and appears to be strengthened by the current experiments, the pattern of performance on the secondary task, presumably reflecting resources required by encoding and retrieval processes, is more complex. Whereas it seems that when cued recall (and recognition; see Craik et al., 1996) is used the secondary task cost at encoding and retrieval is about the same (see results of Experiment 1 here), when a free-recall task, which requires more self-initiated processes (Craik, 1986), is used there is an extra associated cost (Experiment 2 here and Experiments 1 and 2 in Craik et al., 1996). One purpose of the current research was to assess and localize those larger secondary task costs that are associated with the protection of memory retrieval from the effects of DA in a free-recall paradigm. Using a tracking task methodology that allows microlevel measurement of changes in the attentional resources allocated to a task (Experiment 2), we showed that this extra cost at retrieval is distributed evenly during the retrieval phase and is not specific to the periods around the retrievals themselves. This last result strengthened the results of Craik et al. (1996) using a post hoc analysis, which showed no change in secondary task performance in free recall as a function of the number of items retrieved in a given interval. Interestingly, the pattern obtained here for retrieval differs from encoding, where there is a significant cost in secondary task performance around the time when the items are presented and presumably encoded.

What does this continuous cost in a free-recall task at retrieval reflect? Although we have no direct evidence for any specific mechanism involved, a few possibilities may be entertained. It might be that in a free-recall task, the periods between retrievals reflect a continuous search of the memory node network for some candidates for retrieval. This search may require extended continuous attention and resources. Alternatively, this cost may reflect a failure to retrieve some items. We have collected some preliminary data in our laboratory indicating that an unsuccessful retrieval may require as many resources as a successful one.

One issue for future investigation is related to the identification of the subprocesses at retrieval (and at encoding) that utilize the resources reflected by the secondary task costs. One theoretical framework that may help in outlining the taxonomy of possible subprocesses is that advanced by Tulving (1983), who claims that explicit retrieval is assumed first to involve entering a retrieval mode. Tulving (1983) defined a retrieval mode as "when the system is set for treating events as cues to stored episodes" (p. 170). The results of Experiment 1, which show a much larger cost associated with the first retrieved word, a cost that surpasses slowing due to "getting used to the task," may reflect the attentional resources associated with initiating and entering a retrieval mode. In addition, the uniform large secondary task cost in a free-recall paradigm in Experiment 2 of this article is compatible with the maintenance of a retrieval mode throughout the retrieval phase.

The second component of such a supposed retrieval mechanism may be cue elaboration (e.g., Tulving, 1983). This process involves using either external or internal cues that initiate a search of other cues, finally terminating once enough cue information is available, allowing the ecphory process to take place. Such a process is supposed to require appreciable attentional resources. The results of Experiment 1, indicating that retrieval of low frequency words was protected under DA at retrieval, but with increased costs in secondary task performance, may imply that the frequency manipulation affected the processes related to cue elaboration.

Finally, a third component suggested to be involved in retrieval is ecphory, which is the process associated with the successful recovery of the stored information (Moscovitch, 1992; Tulving, 1983). Ecphory is described in the literature as a process that is automatic in nature, one that requires only minimal resources, although this remains untested empirically. The results of Experiment 1 indicating the protection of memory performance under DA at retrieval when the retrieval cue changes perceptually from encoding, with no associated increased costs in secondary task performance, may imply that the perceptual similarity manipulation affected the processes associated with ecphory.

Such a tentative componential analysis of the retrieval process is compatible with recent results of studies using brain-imaging techniques. With respect to the operation of a retrieval mode, Kapur et al. (1995) asked participants to encode information about words. Then participants made old–new recognition decisions under two conditions. In one condition, 34 of the 40 words shown during retrieval were targets, whereas in the other, only 6 of the 40 words were targets. The results showed that both recognition conditions were associated with equivalent activations in the right prefrontal cortex, and that the high-target condition showed additional bilateral activations in the medial parietal cortex in the region of the precuneus. This pattern of results was interpreted as showing that the right prefrontal activations signaled retrieval attempt or retrieval mode, and that the posterior activations in the high-target situation were associated with the actual recognition of the word stimuli (ecphory).

Taken together, the effects of DA at encoding and retrieval on memory performance and the associated secondary task costs suggest that encoding and retrieval processes may be different in important ways. Whereas encoding processes seem to be controlled—as they are significantly affected by division of attention, influenced by instructions to shift attention from one task to the other, and require resources for their execution—retrieval processes seem to operate in an obligatory manner; they are only minimally affected by division of attention and are not influenced by instructions regarding prioratization of tasks, but nevertheless require substantial resources for their execution, especially when a free-recall task is used.

Do the findings reported in this article and by Craik et al. (1996), along with those using neuroimaging techniques to show asymmetry in encoding and retrieval processes, indicate the demise of the notion that retrieval processes recapitulate encoding processes? We think that this notion and our results are not necessarily contradictory. As pointed out in our recent work (Craik et al., 1998), it seems that, logically, the brain correlates of encoding and retrieval must overlap to some degree, given that both sets of processes pertain to the same initial event. The recent research findings appear to indicate that the control processes associated with encoding and retrieval are quite different; it still seems likely, however, that the same cortical areas concerned with an event's representation are activated when the event is encoded, and again when the event is retrieved. Further research addressing these issues would allow the development of a more comprehensive theory regarding the two sets of processes involved in memory: encoding and retrieval.

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