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Short-Term Forgetting of Order Under Conditions of Reduced Interference

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Three experiments examined the short-term retention of order in a modified Brown–Peterson task. Our intent was to examine the loss of order memory, unconfounded by item memory, under conditions in which interference from prior trials is kept low. In previous work on the short-term forgetting of order, experimenters have tended to repeat the same items across trials or to draw from a restricted set; in our experiments, we changed the to-be-recalled items from trial to trial and used reconstruction as the retention measure. In all three experiments, very little forgetting was obtained across retention intervals that have traditionally produced dramatic and systematic loss. Our results are reminiscent of those obtained in the Brown–Peterson task when performance is assessed after only the first experimental trial.

In the typical Brown–Peterson experiment (Brown, 1958; Peterson & Peterson, 1959), subjects are presented with a short list of items (e.g. three words or a consonant trigram), followed by a distractor-filled retention interval of varying duration. At the point of recall, the task is to remember the list items in their correct serial order. Under these conditions, forgetting is often dramatic. In one condition, for example, Peterson and Peterson (1959) found that subjects responded correctly over 70% of the time following 3 sec of distraction. After 18 sec, the percentage of correct responses had dropped to 15%.

One advantage of requiring serial recall is that separate estimates of forgetting can be obtained for recall based on an ordered or free-scoring criterion. Direct comparisons of these measures reveal that ordered recall shows much more forgetting than does free recall, in which items are scored without regard to original serial position (e.g. Marsh, Sebrechts, Hicks, & Landau, 1997; Muter, 1980; Sebrechts, Marsh, & Seamon, 1989). Muter (1980) found, for example, little difference between ordered and unordered scoring on immediate tests, but there were advantages for unordered scoring of 20–30% at retention intervals of 2, 4, and 8 sec. One might interpret these results as suggesting that order information is lost rapidly from memory, but serial recall has the disadvantage of confounding memory for order with memory for the items themselves. A scoring criterion based on ordered recall therefore measures not only the loss of order information, but the loss of item information as well.

A more accurate assessment of the rate at which order information is lost comes from experiments using order reconstruction as the retention measure. In reconstruction tasks,

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the critical item information from a trial is known by the subject or provided at test. It is the subject's task to place items back into their original order of presentation. Because the item information is made available at the time of testing, reconstruction is thought to be a purer test of order or position memory (Healy, 1974; Nairne, 1990, 1991). In classic experiments by Healy (1974), subjects were presented with lists of four consonants, followed by digit-tracking distractor tasks in which they read aloud either 3, 8, or 18 digits, presented individually for 400 msec apiece. After the final digit, subjects attempted to write down the four items, in any order, into four boxes that corresponded to the temporal order of occurrence. In experiments of this type (called Order Only) the same items are used on every trial and are made available at test, so it is necessary only to remember the proper orderings on a trial. Typically, Order Only experiments have revealed relatively rapid forgetting of order; for instance, memory for the order of four unrelated consonants drops about 30% going from 1.2 to 7.2 sec of distraction.

However, memory for order is not always lost at such a rapid rate. A more recent set of studies by Healy and her colleagues (Cunningham, Healy, Till, Fendrich, & Dimitry, 1993; Healy, Fendrich, Cunningham, & Till, 1987), using a new kind of procedure, has produced considerably slower forgetting rates. In the new procedure, subjects are presented with two four-consonant lists, or segments, separated by the presentation of an exclamation mark(!). The same four items appear in each segment across all trials, but subjects are required to reconstruct the order of only one of the two segments at test. In those conditions in which presentation rates, retention interval durations, and testing conditions were most similar to the earlier Order Only experiments, the decline in performance, though variable, has been as low as 7%.

How do we account for these rather dramatic differences in forgetting of what is ostensibly pure order information across the various procedures? One possible explanation is that proactive interference (PI: Keppel & Underwood, 1962) was able to build up much more rapidly in the original Order Only experiments because subjects were both presented with and tested over the same set of items on each trial. Although the same items were presented across trials in Healy et al. (1987) and Cunningham et al. (1993), subjects were not consistently tested over the same set of consonants on each trial in these experiments. Given that PI is considered to be one of the major determinants of forgetting in immediate memory experiments, PI should always be considered as a prime candidate for interpreting apparent forgetting differences across experimental conditions.

Surprisingly, to our knowledge no one has examined the retention of order information under conditions in which PI is effectively minimized. Repeating the same items across trials, or at least drawing from an extremely restricted set, is the norm for studies interested in examining the immediate retention of order information. The reasoning is straightforward—by repeating items across trials, subjects are assured of remembering the appropriate item information on a trial, and thus a more accurate assessment of order retention can be obtained. Unfortunately, controlling for item information is gained with a potentially substantial cost—the proactive effect of prior trials is likely to overestimate the rate of order loss.

In the present experiments, we sought to obtain a better estimate of order loss by having subjects reconstruct the order of a number of short word lists, but each list contained a new set of words (i.e. items not previously encountered within the experiment). Because reconstruction is used as the retention measure, we could effectively control for item information while at the same time reducing the potential for across-trial confusions. Experiments 1 and 2 examined the retention of order information over retention intervals ranging from 2 to 96 sec. Experiment 3 attempted to isolate the effects of across-trial repetition of items: In one condition, different items were used across all trials. In a second condition, replicating the procedures of past studies, the five-item lists were created by repeatedly sampling from a restricted set of 10 items.

EXPERIMENT 1

In Experiment 1, subjects were presented with lists of five items. The final item of each list was immediately followed by a retention interval of 2, 8, 16, or 32 sec filled with digit shadowing. After the distractor interval, the five list items were presented again in a new random order. The subject's task was to reconstruct the order of the original presentation.

Method

Subjects and Apparatus

Subjects were 48 Purdue University undergraduates who participated for course credit. Subjects were tested in individual sessions lasting 1 hr. Stimuli were presented and controlled by IBM-compatible computers.

Materials and Design

The words were 180 medium- to high-frequency nouns, four to seven letters in length, taken from Paivio, Yuille, and Madigan (1968). By randomly sampling from this pool, 36 five-item word lists were created. The ordering of words within each list was randomly determined and remained constant for all subjects. Four practice lists preceded 32 experimental trials. Practice trials employed a random ordering of the different retention intervals.

Four retention intervals were employed in a within-subject design: 2, 8, 16, and 32 sec. Using a 4 × 4 Latin Square, lists were assigned in blocks of four to a particular sequencing of retention intervals. Randomization across blocks of lists was achieved by randomizing the row orderings of this same Latin Square. Thus, each list served an equal number of times under each of the four retention intervals. Subjects had no way of knowing which of the four retention intervals would appear on a given trial.

Procedure

Each trial began with the word READY accompanied by a tone, followed by presentation of the five list items. Items were presented for 750 msec with a 250 msec inter-stimulus interval. Subjects read each word aloud as it appeared on the screen. Following the final item of each list, subjects engaged in a digit-tracking distractor task for 2, 8, 16, or 32 sec. This task involved reading aloud digits (0–9) that appeared individually at the centre of the computer screen at a rate of 500 msec per digit. This distraction interval was immediately followed by the order reconstruction task.

For the reconstruction task, the five list items were re-presented in the centre of the computer screen, but in a new random order. The subject's task was to write the items on a sheet of paper in their original order of presentation. The paper contained blank spaces for the responses next to each of the numbers 1–24. Subjects were instructed to fill in each of the first five response blanks and not to repeat any item. No restrictions were given about the order of responding, and no time limits were imposed. Items remained on the screen until the space bar was pressed to initiate the next trial.

Results and Discussion

Statistical reliability was measured at the $p < .05$ level for all analyses. Only those items that were placed in their correct within-list positions were counted as correct. The proportions of correct responses as a function of retention interval are shown in Table 1. A 4 (retention interval) × 5 (serial position) analysis of variance (ANOVA) revealed reliable main effects of retention interval, $F(3, 141) = 4.30$ ($MSE = 0.052$), and serial position, $F(4, 188) = 61.79$ ($MSE = 0.028$). The interaction did not approach significance, $F(12, 564) = 1.52$ ($MSE = 0.014$). The serial position data are presented in the Appendix and reveal standard bow-shaped serial position effects at each of the four retention interval conditions. The proportion of correct reconstruction responses decreased with increases in retention interval, but the drop in performance was slight. Planned comparisons indicated that only the differences between the 2-sec and 16-sec and between the 2-sec and 32-sec retention intervals were significant, $Fs(1, 141) = 8.40$ and 9.99 ($MSE = 0.052$), respectively.

Whereas Healy (1974, 1975, 1982) showed drops in reconstruction performance of nearly 30% over 6–7 sec of distractor interval, our subjects showed only a 7% drop over 30 sec of distraction. From the 2–8 sec distractor intervals, performance dropped by only 4%, a nonsignificant difference. For the 48 subjects, 26 showed better performance after 2 sec of distraction than after 8 sec, 16 subjects showed the opposite pattern, and 6 were the same. This experiment indicates that there is very little loss of order information across retention intervals when reconstruction is used as the retention measure and different items occur on every trial. It is still possible, however, that forgetting becomes more dramatic for lists of different items at retention intervals longer than those used here. Experiment 2 examined this possibility by testing reconstruction performance across longer retention intervals than those used in Experiment 1.

TABLE 1
Overall Reconstruction Performance for Experiments 1, 2, and 3

	Retention Interval							
Experiment	*2*	*4*	*8*	*16*	*24*	*32*	*48*	*96*
1	.78	—	.74	.71	—	.71	—	—
2	—	.81	—	—	.74	—	.77	.73
3 different	.78	—	.79	—	.72	—	—	—
same	.74	—	.64	—	.57	—	—	—

Note: Different = Different items across trials. Same = Repeated items across trials.

EXPERIMENT 2

Experiment 2 followed the procedures of Experiment 1 in all details except for the range of retention intervals used. Everyone was required to reconstruct the presentation order of five-item lists following distraction intervals ranging from 4 sec to over 90 sec.

Method

Subjects and Apparatus

Subjects were 32 Purdue University students who participated for course credit; none had participated previously in Experiment 1. The stimuli were presented and controlled by IBM-compatible computers.

Materials and Design

The stimulus materials used in Experiment 1 were used again in Experiment 2. A new series of list-retention interval combinations was created as before. The four new retention intervals lasted for 4, 24, 48, or 96 sec.

Procedure

Except for the change in retention interval durations, the procedure of Experiment 2 matched that of Experiment 1 in all details.

Results and Discussion

As in Experiment 1, items were scored as correct only if they were placed in their correct within-list position. Table 1 shows the proportions of correct responses as a function of retention interval. An ANOVA on these data revealed reliable effects of retention interval, $F(3, 93) = 4.34$ ($MSE = 0.059$), and serial position, $F(4, 124) = 45.05$ ($MSE = 0.017$); the interaction did not approach significance, $F(12, 372) = 1.10$ ($MSE = 0.015$). The serial position effects, shown in the Appendix, were once again bow-shaped at each of the retention intervals. Most importantly, there was some decline in performance at the longer retention intervals, but the decline was slight. Planned comparisons revealed significant differences only between retention intervals of 4 and 24 sec and 4 and 96 sec, $F(1, 93) = 2.81$ and 3.35 ($MSE = 0.059$), respectively. Over 90 sec of additional distraction produced a drop in performance of only 8%. Experiment 2 therefore replicates the results of Experiment 1 and once again indicates that the loss of order information is minimal when lists are constructed of different items on each trial.

EXPERIMENT 3

To assess the effects of repeating items across trials directly, subjects in Experiment 3 reconstructed two different blocks of five-item lists. In one block, each trial consisted of five new items not seen previously in the experiment, as in the prior experiments. In the other block, the five-item lists were constructed by repeatedly sampling from a restricted set of 10 items. The presentation, distraction, and test procedures of Experiment 3 were identical to those of the previous experiments except for a change in the retention intervals. In this experiment, subjects reconstructed the order of each five-item list following 2, 8, or 24 sec of digit-tracking distraction.

Method

Subjects and Apparatus

Thirty-six Purdue University students participated in individual sessions lasting approximately 1 hr; none had participated previously in Experiments 1 or 2. The stimuli were presented and controlled by IBM-compatible computers.

Materials and Design

The stimulus materials used in Experiment 3 were drawn from the same pool used in Experiments 1 and 2. For use on the repeated-item trials, ten words were randomly selected. The ordering of these ten items was randomized 12 times, without replacement, to create 24 five-item lists. For the different-item trials, 27 five-item lists were created by sampling randomly as in the previous experiments. Three of these lists served as stimuli for practice trials. The remaining 24 lists served as materials for the different-item condition.

Following the procedure of Experiments 1 and 2, repeated-item and different-item word lists were randomly assigned to each retention interval using a 3 $\times$ 3 Latin Square. Three retention intervals were used: 2, 8, and 24 sec.

Procedure

The presentation, distraction, and reconstruction task demands were identical to those used in Experiments 1 and 2. A random half of the subjects received the block of repeated-item lists prior to the block of different-item lists. The other one-half received the reverse ordering. Three practice trials, one for each retention interval, preceded the 48 experimental trials.

Results and Discussion

For each list type, items were scored as correct only if they held their correct within-list serial position. Table 1 shows the proportion of correct responses as a function of list type and retention interval. A 2 (list type) $\times$ 3 (retention interval) $\times$ 5 (serial position) ANOVA revealed reliable main effects of list type, $F(1, 35) = 32.46$ ($MSE = 0.105$), retention interval, $F(2, 70) = 24.14$ ($MSE = 0.052$), and serial position $F(4, 140) = 75.71$ ($MSE = 0.025$). There was also a significant List $\times$ Retention Interval interaction, $F(2, 70) = 9.06$ ($MSE = 0.037$), a List $\times$ Serial Position interaction, $F(4, 140) = 2.53$ ($MSE = 0.018$), and a Retention Interval $\times$ Serial Position interaction, $F(8, 280) = 3.85$ ($MSE = 0.018$). The three-way List Type $\times$ Retention Interval $\times$ Serial Position interaction was not significant, $F < 1$.

Of main interest is the List Type × Retention Interval interaction. As shown in Table 1, the decline in performance with an increasing retention interval was much more pronounced when items were drawn from a restricted set. When different items were used across trials, performance losses were quite small. Planned comparisons revealed significant differences among all means when items were repeated across trials, $F(1, 136) = 18.05$, 59.66, and 12.08 (*MSE*s = 0.044), for the 2- and 8-, 2- and 24-, and 8- and 24-sec interval comparisons, respectively. When items changed from trial to trial, there was significantly lower performance for the 24-sec retention interval compared to the 2- or 8-sec intervals, $F(1, 136) = 7.62$ and 9.41 ($MSE = 0.044$), respectively; the 2- and 8-sec means did not differ from one another, $F < 1$. Finally, and importantly, performance at the shortest retention interval did not differ across the two list types, $F(1, 82) = 2.64$ ($MSE = 0.06$).

These data suggest that the build-up of PI, when items are repeated across trials, is an important source of order forgetting over the short-term. Also, replicating Experiments 1 and 2, Experiment 3 demonstrates that order information is lost relatively slowly when memory lists contain unique items on every trial. Although the rate of loss for the restricted set condition was not as rapid as that shown in Healy's experiments, our pool of items (10) was larger than the largest pool (8) used by Healy (1982, Experiment 1). The fact that we used word stimuli in our experiment may also have contributed somewhat to the rates of forgetting that we obtained (see, e.g. Murdock & Hockley, 1989). This possibility is entertained in greater detail in the general discussion.

GENERAL DISCUSSION

The results of Brown–Peterson experiments are commonly interpreted as providing strong support for the idea that information is lost rapidly from short-term memory in the absence of rehearsal. However, this is a gross oversimplification of these results because this conclusion is based on serial recall performance (e.g. Brown, 1958; Murdock, 1961; Peterson & Peterson, 1959). As mentioned in the introduction, serial recall requires subjects to remember both the items and the order in which the items occurred. The estimates of forgetting obtained in typical Brown–Peterson experiments is therefore based on the loss of both item and order information. The loss of information from short-term memory is much less drastic when purer measures of item (e.g. Marsh et al., 1997; Muter, 1980; Sebrechts et al., 1989) and order (e.g. Healy, 1974, 1975, 1982) information are used.

The experiments described in this paper were undertaken to examine the retention of order information across various retention intervals under conditions in which interference from prior trials is minimized. Although Healy's (1974, 1975, 1982) experiments showed less forgetting of order than is suggested by typical Brown–Peterson experiments, the amount of forgetting was still fairly large. We reasoned, however, that Healy's experiments might be overestimating the rate of order loss because items were repeated across trials, allowing for the rapid build-up of PI. In our experiments, we attempted to minimize PI by using different items on every trial. We are not claiming to have eliminated PI, which is probably impossible for all practical purposes, but it is reasonable to assume that subjects are less likely to confuse current trial information with prior trial information when items occur no more than once in a study. In Experiments 1 and 2, little forgetting was found over retention intervals ranging from 2 sec to over 90 sec. In Experiment 3, we found more rapid forgetting, but only when items were repeated across trials. These data are consistent with our speculation that the repetition of items across trials allows for a rapid build-up of PI.

It is equally important to stress, however, that we did obtain significant forgetting in each of our experiments. There was a significant decline in order memory with an increasing retention interval, although at a rate far slower than is traditionally found. It is also worth noting that performance at the shortest retention intervals was well off the ceiling of perfect performance. We did not include a 0-sec retention interval in our experiments, but it seems likely that performance would improve with immediate testing. To check on this possibility, we tested an additional set of 24 subjects, in a design similar to Experiment 3, except that we included a 0-sec (no distraction) condition along with a 2-sec distractor condition. At the 0-sec delay, performance did not depend on whether the same or different items were repeated across trials (different items = .81; same items = .80). At the 2-sec delay, performance dropped significantly for both conditions, and more forgetting was found when the same items were repeated across trials (different items = .68; same items = .62).[1]

The fact that performance dropped from a 0-sec to a 2-sec retention interval is noteworthy, but not surprising; it is also quite difficult to interpret. One possibility is that components of the short-term memory trace decay rapidly between 0 sec and 2 sec (e.g. Tehan & Humphreys, 1995). Baddeley and Scott (1971) found that when subjects were tested after only a single trial in the traditional Brown–Peterson task, there was some forgetting after a few seconds of distraction, but it reached asymptote after about 5 sec. Our results showed a similar pattern: There is significant loss between 0 sec and 2 sec, but little further decline with increasing retention interval. It is important to note, however, that the comparison between a 0-sec and a 2-sec delay is confounded by the presence or absence of a distractor task. The vocalization of rapidly presented digits could interfere with retention of the memory list for a number of reasons—such as through the over-writing of sensory features, interference with encoding processes, or through lowering storage resources. In our opinion, the more interesting comparisons are those among conditions that include distractor tasks, but where the distractor tasks vary in length. In our case, we observed little forgetting of order after an initial short (2-sec) period of distraction unless items were repeated across trials.

It is possible that the use of words in our experiments might account for the slower rates of forgetting that we found. Healy et al. (1987) and Cunningham et al. (1993) did find slow rates of order information loss using letter stimuli. However, we cannot be

[1] Note that performance at the 2-sec retention interval is lower than in Experiments 1–3. This may have been due to the fact that we required subjects to respond via the computer in this additional experiment rather than by writing down responses on paper.

certain that the same slow rates of order loss would be obtained under our procedures when different letters, as opposed to words, were presented across trials. There is evidence, for example, that reconstruction performance relies to some extent on inter-item associations, and it may well be easier for people to associate unrelated words than unrelated letters (Nairne & Serra, 1992). In addition, a good deal of evidence that suggests that inter-item associations are forgotten quite slowly from memory is beginning to accumulate (e.g. Hockley, 1992; Murdock & Hockley, 1989). The possibility that our result is limited to word stimuli (or other easily associated items) is therefore a real one.

It is our belief that the data of the current experiments—particularly Experiment 3—further reinforce the view that any full account of forgetting in immediate memory will need to appeal in some way to interference, and to PI in particular. Nairne, Neath, and Serra (1997) recently showed that another benchmark finding in immediate memory—the word length effect—also depends on the presence of PI. The mnemonic advantage that short words show over long words in immediate memory span is usually attributed to autonomous decay processes (e.g. Baddeley, 1992)—that is, long words take longer to say, and thus fewer words can be rehearsed within a fixed decay window. However, Nairne et al. (1997) found no evidence for a word length effect on early trials in a session; the short-word advantage emerged only after several trials, indicating that PI is a necessary requisite for the appearance of the word length effect. Exactly why the presence of prior trials leads to word length effects and to the presence of interval-based forgetting remains unclear, but it does represent a significant empirical challenge to theoretical accounts of short-term memory.

One might be able to explain the current results by appealing to a two-process account, which proposes that immediate memory performance reflects the contribution of, or trade-off between, separate short- and long-term memory systems. When PI is minimized, through the use of different items on every trial and reconstruction as the retention measure, subjects might be able to recover trial information relatively easily from long-term memory, effectively masking the contribution of a decay-based short-term memory system. When the same items are used on every trial, as in Experiment 3 and most other studies of immediate retention, the mnemonic representations from prior trials clutter long-term memory, and subjects shift strategically to recovery from short-term store. An account of this type has been proposed previously to explain the classic data of Keppel and Underwood (Atkinson & Shiffrin, 1968; Cowan, 1995), and it could be applied to the present results.

However, a "shifting stores" account remains largely speculation at this point. There is no direct empirical evidence confirming that subjects strategically shift from short to long-term retrieval within an experimental session. Moreover, Nairne and Kelley (in press) have shown that the phonological similarity effect remains in immediate serial recall when different items are used on every trial and reconstruction is used as the retention measure (see also Coltheart, 1993); if subjects tended to rely on recovery from long-term memory—which is presumably semantically based—in an "uncluttered" environment, then the phonological similarity effect should have been reduced or eliminated when different items were used across trials. There is also a significant amount of evidence indicating that memory performance over the short and long term follows similar rules (see Nairne, 1996, for a review), so whether sufficient evidence exists for the postulation of separate short and long-term memory systems is a matter of debate. What remains, however, are the data: The results of the current experiments confirm that forgetting rates in immediate memory are highly variable, depending importantly on the presence or absence of interfering materials from prior trials.

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Appendix
Serial Position Effects for Experiments 1–3

		Serial Position				
Experiment		*1*	*2*	*3*	*4*	*5*
1	RI = 2	.92	.73	.66	.70	.86
	RI = 8	.87	.73	.66	.67	.80
	RI = 16	.85	.72	.62	.64	.72
	RI = 32	.84	.70	.65	.61	.73
2	RI = 4	.93	.83	.74	.74	.84
	RI = 24	.85	.72	.67	.69	.78
	RI = 48	.88	.76	.72	.68	.81
	RI = 96	.82	.68	.66	.66	.82
3 difference	RI = 2	.90	.74	.63	.71	.92
	RI = 8	.87	.78	.68	.73	.87
	RI = 24	.83	.69	.63	.65	.80
repeated	RI = 2	.90	.67	.65	.61	.87
	RI = 8	.75	.61	.57	.59	.71
	RI = 24	.64	.52	.53	.52	.62

Note: RI = retention interval.