

**Supplementary Material to
Oberauer, K. & Lewandowsky, S. (2008). Forgetting in Immediate Serial Recall:
Decay, Temporal Distinctiveness, or Interference? *Psychological Review***

Methods and Results of Experiments 3 to 5 in Table 1

Experiment 3

There were 5 conditions: a baseline condition without any delays at either encoding or retrieval; and four delay conditions: one or three distractors at encoding; and one or three distractors at retrieval. Distractors involved AS only.

Method

Participants

Participants were 21 psychology students from the University of Potsdam, Germany.

Materials and Procedure

Participants recalled lists of six consonants in order. Each list was generated by randomly ordering the consonants H, J, M, Q, R, and V. At the beginning of each trial, the condition was displayed for 2 s (e.g., “3 × super at retrieval”). List items were then presented at a rate of 1.1 s per item (1 s on, 100 ms off).

In the conditions with delay at encoding, each item was followed by the word “super” (printed in blue font) for 1 s (followed by a blank interval of 100 ms), either once or three times in succession. Participants read each “super” aloud. At the end of the list, the German word for “recall” was displayed for 1 s, and in the conditions without delay at retrieval, a red question mark followed after 100 ms of blank interval. In response, participants recalled the first letter aloud and pressed the space bar to proceed to the next screen. After an 100 ms the computer displayed the next question mark prompting recall of the next letter, and so on. In the conditions with delay at retrieval, each question mark was preceded by one or three screens with the word “super” in blue font. Participants read the distractor aloud and pressed the space bar to proceed to the next screen, which displayed either another “super” or the next question mark; 100 ms blank interval separated each screen from the next. The recalled letters were recorded by the experimenter.

After a practice block with six trials, participants completed four blocks of 15 trials each. The order of conditions was randomized within the set of 60 test trials with the constraint that 12 trials were presented for each condition.

Results

Serial position curves of correct-in-position scores are presented in Figure 1 (top panel for delay at encoding; bottom panel for delay at retrieval). For the ANOVA (summarized in Table 1), serial position was coded as the linear contrast over serial position, and condition was coded by four orthogonal contrasts. The articulatory-suppression (AS) contrast compared the baseline to the mean of the four conditions with delays filled by AS. The encoding-retrieval (ER) contrast compared the two conditions with delays during encoding with the two conditions with delays during retrieval, averaging across the number of distractors. The delay-at-encoding (DE) contrast compared one versus three distractors at encoding. Finally, the delay-at-retrieval (DR)

contrast compared one versus three distractors at retrieval. The main effect of DE tests the time effect at encoding (TEE). The interaction of DF with the linear effect of serial position tests the fanning-out pattern at retrieval. Both these effects were nonsignificant.

The mean times for recalling a letter, measured as the interval from the presentation of a question mark to the participant's key press, were 1.12 s for the baseline condition, 1.68 s and 1.79 s for one and three "supers" at encoding, respectively, and 1.59 and 1.81 s for one and three "supers" at retrieval, respectively. The baseline recall time was significantly shorter than the other four, $F(1, 20) = 29.7$, $p < .001$, $\text{partial } \eta^2 = .60$, and the two conditions with delay at retrieval differed significantly, $F(1, 20) = 6.4$, $p = .02$, $\text{partial } \eta^2 = .24$. At encoding, the time for reading each distractor aloud was fixed to 1 s, but at retrieval, distractor reading was self paced. Participants took an average of 1.4 s ($SD = .37$) for saying "super" when one distractor word preceded each item at retrieval, and they took 0.93 s ($SD = .22$), 0.58 s ($SD = .17$), and 0.98 s ($SD = .38$), respectively, for the three successive "supers" in the condition with three distractors at retrieval.

Experiment 4

This experiment tested delays filled with AS only and delays filled with AS together with a choice reaction task (AS+CRT) in between retrieval attempts. No baseline condition was included.

Method

Participants

Twenty psychology undergraduates of the University of Bristol participated for course credit.

Materials and Procedure

This and all following experiments were programmed using the Psychophysics toolbox (Brainard, 1997; Pelli, 1997). Participants were given lists of five consonants for immediate serial recall. The lists were assembled by drawing items at random without replacement from a pool of 19 consonants (excluding Q and Y). After display of a central fixation cross, items were presented sequentially in the center of the screen at a rate of 0.5 s per item (400 ms on, 100 ms off) in black on a white background.

A cue indicating the condition was displayed immediately after offset of the last list item for 700 ms. Recall of each item was prompted by a question mark. Participants recalled each consonant orally and pressed the up-arrow key to proceed to the next event. One or four distractor events preceded each recall event. In the AS-only conditions, each distractor event involved saying "super" once; in the AS+CRT conditions, each distractor event involved saying "super" once and performing a single CRT simultaneously. When 4 distractor events were presented, they followed immediately upon each other (with a 100 ms blank interval between key press and the next stimulus).

In the AS-only conditions, the stimulus for each distractor event consisted of an asterisk displayed centrally in the upper third of the screen. In response to this stimulus, participants said "super" aloud and pressed the up-arrow key. The next stimulus could be another asterisk (in the condition with 4 distractor events) or a question mark displayed centrally to prompt recall of the next consonant. The recall sequence therefore consisted of a sequence of vocal utterances (either saying "super" or recalling a consonant), each of

which was accompanied by pressing the same key; the key-pressing task thus involved no stimulus-contingent response selection.

In the AS+CRT conditions, the stimulus for each distractor event was an asterisk displayed on the left or the right side of the screen, about two cm from the edge, centered vertically. In response to this stimulus, participants had to say “super” aloud and press the arrow key corresponding to the location of the asterisk (right or left). Each asterisk appeared in a randomly chosen location with equal probabilities. Following the CRT response, the trial continued exactly as in the AS-only conditions.

The experiment consisted of 20 practice trials, followed by 80 test trials (20 in each condition), presented in a new random order for each participant. Trials were separated by a blank interval of 3.5 s. A short break was provided after every 20 trials. The experimental session lasted about 50 minutes.

Results

The serial position curves for the four conditions are shown in Figure 2. The data were analyzed through an ANOVA with serial position, coded as linear contrast; delay (1 vs. 4 distractor events); and distractor condition (AS-only versus AS+CRT) as fully-crossed within-subject variables. The results are summarized in Table 3. The significant interaction of serial position with delay shows that, averaged over both distractor conditions, fanning was again present, with performance dropping more steeply over serial position with four than with one distractor event. The figure suggests that fanning was larger in the AS+CRT condition than in the AS-only condition, as would be expected from the modified Primacy model if attentional rehearsal persisted in the latter but not the former condition. The statistical test, however, did not confirm this impression – the three-way interaction was not significant. The main effect of distractor condition also failed to be significant, implying that the addition of a CRT to each distractor event did not affect overall memory performance.

Notwithstanding the absence of a significant three-way interaction, we tested for fanning in each distractor condition separately to provide a direct comparison with the other experiments. The interaction of serial position (linear contrast) with delay was not significant in the AS-only condition, $F(1, 19) = 3.0, p = .10$, partial $\eta^2 = .14$, but it was in the AS+CRT condition, $F(1, 19) = 7.7, p = .012$, partial $\eta^2 = .29$.

Accuracies for the choice task were 98 % in the condition with one distractor event and 94 % in the condition with four distractor events. The mean latencies for recalling one item (computed after exclusion of 9 outlying latencies exceeding 15 s), including the times spent on the preceding distractor events, were 2.13 s (SD = .69) for one distractor word and 3.64 s (SD = .93) for four distractor words in the AS-only condition. In the AS+CRT condition, latencies were 2.25 s (SD = .84) for one distractor event, and 4.39 s (SD = .93) for four distractor events. An ANOVA with distractor condition and delay as independent variables showed that latencies were longer when a choice task was added to the distractor word, $F(1, 19) = 41.6$, partial $\eta^2 = .69$, and unsurprisingly, they were longer with four than with one distractor event, $F(1, 19) = 654.6$, partial $\eta^2 = .97$. The interaction was also significant, $F(1, 19) = 28.79$, partial $\eta^2 = .60$; all $p < .001$. With a single distractor event, latencies did not differ, $t(19) = 1.36$, but the addition of a choice task increased latencies with four distractor events, $t(19) = 8.47$.

Experiment 5

This experiment was complementary to Experiment 4, using one or four distractors at encoding. Distractors were either AS-only or AS+CRT.

Method

Participants

A new sample of 20 psychology undergraduates of the University of Bristol participated for course credit.

Materials and Procedure

Materials were as in Experiment 4. Each trial started with a message indicating the upcoming condition, displayed for 700 ms, followed by a fixation cross for 800 ms. After the fixation cross disappeared, five consonants were presented for 500 ms each (400 ms on, 100 ms off). Participants were instructed to read the consonants aloud. In the delay conditions, each consonant was immediately followed by a distractor event. Distractor events were exactly as in Experiment 4. After participants ended a distractor event by pressing the appropriate key, the next distractor event or the next memory item was displayed after a 300 ms blank interval. After the last list item or distractor event, recall was prompted by a question mark. After recalling a letter orally, participants pressed the up-arrow key to proceed to the next question mark.

Results

The results are shown in Figure 3. The right side of Table 2 summarizes the results of an ANOVA analogous to that of Experiment 4. The result of most theoretical interest is the interaction of delay with serial position: In both AS-only and AS+CRT conditions, longer delays were associated with better performance, increasing toward the end of the serial position curve.

Accuracies for the choice task were .98 and .96 for one and four distractor events, respectively. One latency was removed as outlier. In the AS-only condition, mean latencies were 1.51 s (SD = .31) with one distractor and 2.64 s (SD = .55) with four distractors. In the AS+CRT condition, latencies were 2.51 s (SD = .35) and 4.14 s (SD = .60) for one and four distractor events, respectively. The main effects of condition and delay and their interaction were all significant, minimum $F = 54.1$.

References

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- Lien, M.-C., & Proctor, R. W. (2002). Stimulus-response compatibility and psychological refractory period effects: Implications for response selection. *Psychonomic Bulletin & Review, 9*, 212-238.
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Table 1: Summary of ANOVA Results for Experiment 3

| | F | p | Partial η^2 |
|----------------------|------|-------|------------------|
| Serial Position | 97.6 | <.001 | .83 |
| AS | 78.4 | <.001 | .80 |
| ER | 15.8 | .001 | .44 |
| DE | 2.4 | .14 | .11 |
| DR | 1.7 | .20 | .08 |
| Serial Position x AS | 9.4 | .006 | .32 |
| Serial Position x ER | 24.4 | <.001 | .55 |
| Serial Position x DE | 4.3 | .052 | .18 |
| Serial Position x DR | 0 | .86 | 0 |

Legend: Serial Position refers to the linear contrast of serial position. AS = articulatory suppression contrast; ER = encoding-retrieval contrast; DE = delay-at-encoding contrast; DR = delay-at-retrieval contrast. Degrees of freedom were 1, 20.

Table 2: Summary of ANOVA Results of Experiments 4 and 5

| | Experiment 4 | | | Experiment 5 | | |
|------------------------|--------------|-------|------------------|--------------|-------|------------------|
| | F | p | Partial η^2 | F | p | Partial η^2 |
| Serial Position (SP) | 202.9 | <.001 | .91 | 26.1 | <.001 | .59 |
| Delay | 9.9 | .005 | .34 | 3.3 | .086 | .16 |
| Condition | 12.5 | .002 | .40 | 58.2 | <.001 | .76 |
| SP x Delay | 9.2 | .007 | .33 | 8.1 | .011 | .311 |
| SP x Condition | 2.0 | .170 | .10 | 0 | .86 | 0 |
| Delay x Condition | 2.5 | .13 | .12 | 3.3 | .085 | .15 |
| SP x Delay x Condition | 1.7 | .21 | .08 | 0 | .85 | 0 |

Legend: Serial Position refers to the linear contrast of serial position. Delay refers to the number of distractor events, and Condition to the kind of distraction (AS only or AS+CRT). In Experiment 4, distractors were inserted at retrieval, and in Experiment 5, distractors were inserted at encoding. All df were 1, 19.

Figure 1: Results of Experiment 3 (Top: Delay at Encoding, Bottom: Delay at Retrieval)

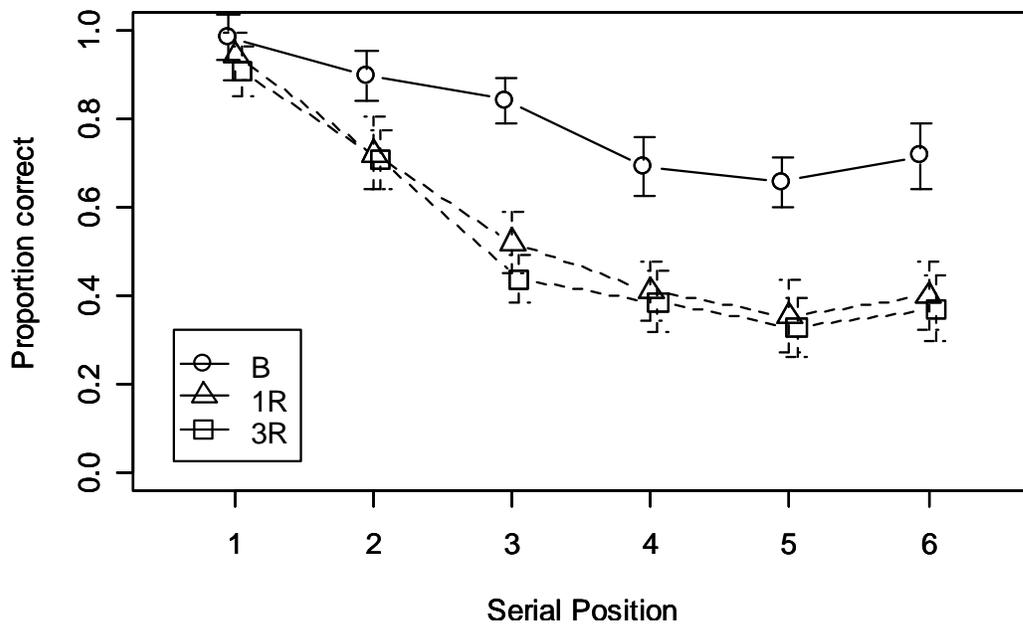
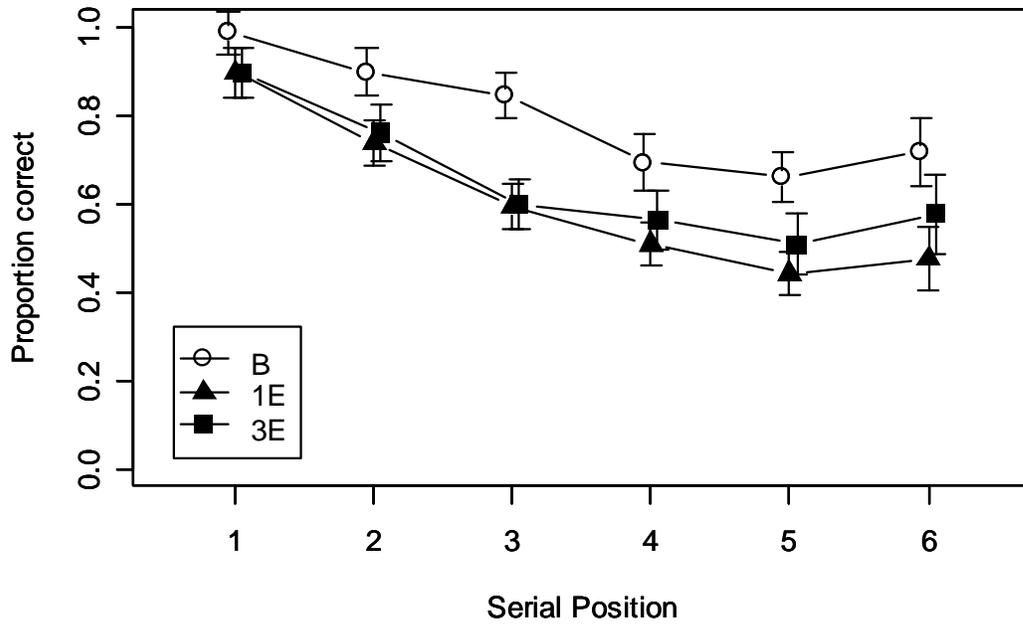


Figure 2: Results of Experiment 4: Serial Position Curves for Delays at Retrieval

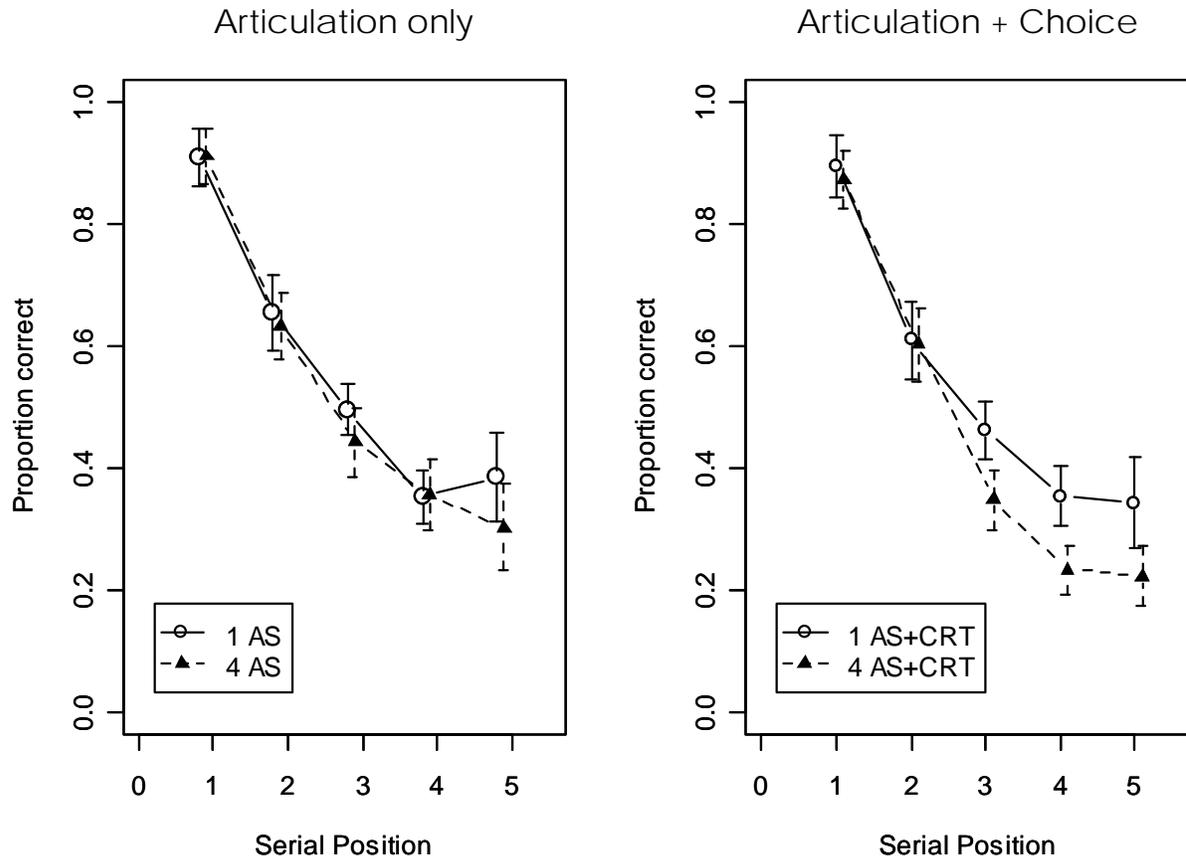


Figure 3: Results of Experiment 5: Serial Position Curves for Delays at Encoding

