Research Report

RECONFIRMATION OF THE SHORT-TERM STORAGE CONCEPT

Nelson Cowan, Noelle L. Wood, and Dawn N. Borne
University of Missouri

Abstract—*Recent research questions the existence of a short-term storage mechanism capable of holding limited information temporarily. Specifically, serial-recall results with a through-list distractor (TLD) procedure, in which a distracting task is interposed between list items as well as between the list and recall period, generally resemble the results of immediate-recall procedures. The present study, however, reconfirms the utility of short-term storage by demonstrating an important difference between immediate and TLD recall. A word-length effect, or advantage for lists of shorter words (which minimize short-term forgetting during spoken recall), did not occur with a TLD procedure.*

A widely employed concept in memory theory is short-term storage, manifest in temporarily heightened accessibility of recently acquired information (Atkinson & Shiffrin, 1968; Broadbent, 1958; Cowan, 1988). In ordinary list-recall procedures that have been used to study short-term storage, which we term immediate-presentation (IP) procedures, a series of words is presented on each trial, and subjects are to recall them, either at once or after a delay period filled with a distracting task. A large role of short-term storage has been inferred from such tasks, partly because there is an advantage for the most recent items that is greatly diminished by a postlist delay period (Glanzer & Cunitz, 1966).

Recently, some investigators have questioned the existence of a separate short-term storage mechanism (Crowder, 1989, 1993; Greene, 1986b; Nairne, 1992). One main source of doubt is research using the through-list distractor (TLD) procedure, in which a distracting task 12 to 30 s long is presented immediately before the list and after each list item. Despite the recall delay imposed by the last distractor period, TLD presentation also produces an advantage for the most recent items (Bjork & Whitten, 1974) and other effects that previously had been attributed to short-term storage (Gardiner & Gregg, 1979; Glenberg, 1984; Greene, 1986a). However, the present article demonstrates that at least one important effect in list recall that has been taken to support short-term storage, the word-length effect (Baddeley, Thomson, & Buchanan, 1975; Cowan et al., 1992), is not replicated when a TLD procedure is used.

Baddeley et al. (1975) found that lists of short words are recalled more successfully than lists of longer words. This phenomenon has been explained on the grounds that the phonological representations of some words are lost from short-term storage while other words are being covertly rehearsed or overtly pronounced, with the extent of loss dependent on the duration of the articulated words (Baddeley, 1986).

Further strengthening the assumption that short-term storage mechanisms underlie word-length effects, Cowan et al. (1992) found that such effects are not based primarily on covert rehearsal. This study manipulated the lengths of words in the first and second halves of the list independently and required either forward or backward recall. The length of words in whatever half of the list was to be recalled first significantly affected performance across the list, whereas the length of words to be spoken later made little difference. The finding was especially striking in backward recall, because only the length of words presented in the second half of the list (those words to be recalled first) had a significant effect, even though the words presented first (to be recalled later) were available for rehearsal longer. This result suggests, as the primary mechanism of word-length effects, that a short-term memory representation of some words deteriorates during the time that it takes to pronounce other words aloud in recall.

The present research replicates the especially diagnostic, backward-recall portion of Cowan et al. (1992) with both IP and TLD procedures. If the short-term storage account of the word-length effect is correct, then this effect should not emerge in the TLD procedure because short-term storage of the items should be lost during the postlist distractor period regardless of word length. If, however, time per se does not matter in list recall (as, e.g., Crowder, 1993, suggested), then similar effects should be obtained with the IP and TLD procedures.

METHOD

Subjects

The subjects, 60 introductory psychology students, received course credit for their participation.

Apparatus and Stimuli

Stimuli were presented on an IBM AT computer screen, in a normal font, with green lettering on a black background. Short (monosyllabic) words were drawn from the set *fan, hat, leaf, snail, toast,* and *yarn,* whereas long (trisyllabic) words were drawn from the set *banana, grandfather, kangaroo, newspaper, policeman,* and *umbrella.* The word sets were matched for word frequency (Carroll, Davies, & Richman, 1971). In practice trials, the words *rabbit, table,* and *window* were used.

Procedure

Subjects were run individually in a quiet room, for about 1.5 hr per subject. Half of the subjects received the IP procedure first, and half received the TLD procedure first. Stimuli were randomized anew for each subject. Within both the IP and the TLD procedures, trials were presented in blocks of four that in-

Address correspondence to Nelson Cowan, Department of Psychology, 210 McAlester Hall, University of Missouri, Columbia, MO 65211; e-mail: psycowan@umcvmb.missouri.edu.

cluded randomly ordered SS, SL, LS, and LL trials, where S and L refer to the short versus long length of words in the first and second halves of the six-item list (e.g., SL signifies three short words followed by three long words). On each trial, the word for each serial position was randomly selected without replacement from the appropriate set (short or long). There were 24 test trials in each procedure. The IP and TLD procedures each began with three practice trials in which the method was the same as in the test trials (to be described), except that each practice list was only three words long.

The experimenter pressed a computer key to initiate each test trial, which began with the word "READY" centered on the screen for 2 s. Immediately after that, six words were presented individually for 1 s each, centered on the screen. In the IP procedure, the 1-s intervals were immediately juxtaposed. In the TLD procedure, however, digits randomly selected from the set 1 through 9 were presented, centered on the screen, one at a time at the rate of 500 ms per digit for 15-s intervals immediately preceding the first word and following each word in the list. In both conditions, the words were spatially surrounded by several blank spaces that were in turn surrounded by asterisks, to help set words apart from the digits used in the TLD procedure. The subject was instructed to read each word and each digit aloud as it appeared on the screen.

The response mode (paced or unpaced) differed for two groups of 30 subjects, though this variable proved not to matter. For the paced-recall group, immediately after the last word or digit disappeared from the screen, the sign "*?*" appeared, and additional "*?*" signs were added, at a rate of 2 s per sign, until six of them appeared on the screen. These signs formed a diagonal pattern beginning about 1 cm below and right of center, and progressing upward and leftward to remind the subject of the backward order of recall. When the last "*?*" sign had appeared for 2 s, the signs were removed and the word "STOP" appeared, centered on the screen. Subjects were to recall the words aloud, backward, at a pace of one word per "*?*" sign, and no recall was permitted after "STOP" appeared. For the unpaced-recall group, however, the last word or digit was followed immediately by a row of six question marks and a 300-ms, 500-Hz tone, and the subject was simply to recall the words backward at whatever pace worked best. Subjects in both groups were encouraged to guess if they could not remember a word, and to say "blank" as a placeholder whenever they could not guess.

Notice that subjects had at least as much time to process and retrieve each word in the TLD procedure as in the IP procedure. Although the shadowing task was quite difficult and likely to have blocked rehearsal in those intervals, subjects managed to follow directions well. The experimenter sat quietly behind the subject, out of view, and recorded the responses. Then the experimenter pressed a key to show the correct sequence on the computer screen, both for recording purposes and to provide feedback to the subject.

Table 1. *Proportion correct for each half-list for the four types of word lists*

Length of words in Serial Positions 1–3 and 4–6	Serial Positions 1–3	Serial Positions 4–6
Immediate-presentation procedure		
Short, short	.39	.82
Long, short	.41	.87
Mean, short second half	.40	.85
Short, long	.38	.85
Long, long	.30	.81
Mean, long second half	.34	.83
Through-list distractor procedure		
Short, short	.37	.48
Long, short	.49	.56
Mean, short second half	.43	.52
Short, long	.44	.61
Long, long	.48	.59
Mean, long second half	.46	.60

Note. Words were to be recalled in backward order.

RESULTS

Each item was scored as correct only if it was reported in the correct serial position counting from the beginning of the list. As there was no hint of an effect of recall pacing, the proportions correct for the various within-subjects conditions are shown collapsed across the two recall-pacing groups in Table 1.

The effects of word length were quite different in the IP and TLD procedures, just as one would expect on the basis of a short-term storage account of the data. In the IP procedure, which closely replicated Cowan et al. (1992) with a different set of words, the critical findings were an advantage for lists with a second half comprising short rather than long words, $F(1, 58) = 11.51$, $p < .002$, and the absence of a comparable effect of first-half-list word length, $F(1, 58) < 1$ (see top halves of Table 1 and Fig. 1). As shown in the figure, the effect of second-half-list word length was largest for the first few serial positions. This was as expected given that the first few list items were the ones recalled last; their short-term memory representations could be lost while items closer to the end of the list were being recalled. Supporting this interpretation, the Second-Half-List Word Length × Serial Position interaction was significant, $F(5, 290) = 4.02$, $p < .002$.

The IP results did differ slightly from those of Cowan et al. (1992), who observed a slight upturn for the list item recalled last, above the level for the previously recalled item. A difference between studies that could have produced this minor discrepancy is that only subjects in the present study knew before the list presentation that they would have to recall the list backward. As a

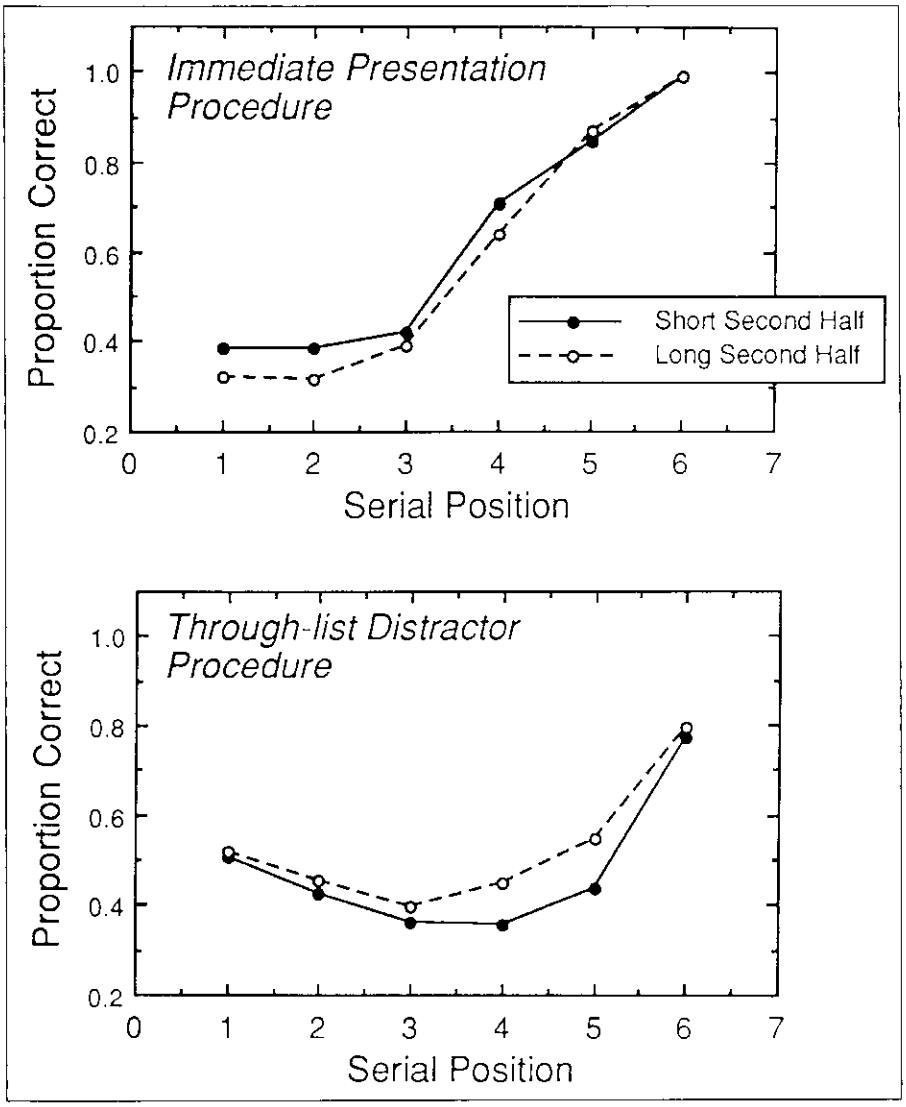

Fig. 1. Proportion of correct responses for each input serial position in the immediate-presentation (IP) procedure (top) and the through-list distractor (TLD) procedure (bottom), for lists with short words (solid lines) versus long words (dashed lines) in the second half-list. (Results are collapsed across lists with short versus long first halves.) Words were to be recalled in backward order. The IP results closely replicated Cowan et al. (1992), but an advantage for short words was not obtained in the TLD results.

result, they may have used a special rehearsal strategy in which the first serial position was deemphasized.

In the TLD procedure, in striking contrast to the IP procedure, performance was better for lists in which the first half contained long rather than short words, $F(1, 58) = 17.58$, $p < .001$, and also for lists in which the second half contained long rather than short words, $F(1, 58) = 20.26$, $p < .001$. These reversed word-length effects are shown in Table 1, and, for the sake of comparison with the IP procedure, the second-half word-length effect is shown by serial position in the bottom half of Figure 1. Clearly, the ordinary advantage for short words emerged only with a truly short-term recall procedure, not with a distractor period after each list item.

The unimportance of response pacing for the pattern of word-length effects further clarifies the nature of short-term memory loss in the IP procedure. Apparently short-term memory loss does not occur constantly during the recall period; it occurs primarily while the subject is speaking, a duration that is affected by word length but not by response pacing. The reason may be that subjects can use covert processes to refresh their memory during interword pauses within their responses, a hypothesis that is supported by evidence that memory span is related to the speed of processing during interword pauses (Cowan, 1992; Cowan et al., in press).

Because the advantage for long words in the TLD procedure was unanticipated, possible bases of this effect were investigated in a new group of 20 subjects. One possibility was that the short words were more similar to one another than the long words. To examine this possibility, we asked subjects to judge the similarity of pairs of words from the memory lists on a scale from 1 (very similar) to 10 (very dissimilar). The subjects were told that similarity ratings could "take into account the words' meanings, how they are written, and how they are spoken." No significant difference in the judged interitem similarity of short ($M = 6.88$) versus long ($M = 6.73$) words was observed. We also investigated the possibility that short words were more difficult to form a mental image of than long words. The words from the memory lists were judged individually on a scale from 1 (very easy to form an image) to 10 (very difficult to form an image). The short words ($M = 2.43$) were judged slightly more difficult to image than the long words ($M = 1.92$), $F(1, 19) = 7.39$, $p < .02$.

In sum, although a difference in imageability could explain the advantage for long words in the TLD procedure, in the IP procedure, short words were recalled best despite their imageability disadvantage. It would be difficult to account for this finding without proposing that an additional mechanism comes into play in the IP procedure. The results of the memory experiment suggest that the additional mechanism is short-term memory loss during spoken recall, with greater loss occurring during the recall of longer words.

DISCUSSION

Some investigators have emphasized the similarity of findings in the ordinary IP and the TLD versions of serial verbal recall and have used these similarities to argue that there is no special short-term

storage mechanism (Crowder, 1989, 1993; Greene, 1986a, 1986b). The present research indicates that there are important differences between the IP and TLD results, with only the IP procedure yielding the advantage for short words that was discovered by Baddeley et al. (1975) and refined by Cowan et al. (1992). The differences observed can be explained by the assumption that there is a transient form of memory representation that cannot operate over long distractor-filled intervals. This form of memory would work in combination with other factors, such as the temporal distinctiveness of items in the list, that apply at either short or long intervals. The present study thus reconfirms the utility of the concept of a functionally separate short-term memory storage system.

Acknowledgments—This work was completed with support from National Institutes of Health Grant HD-21338. We thank Ken Spencer for assistance in programming and Christine Bow-Thomas, Tim Keller, and Michael Stadler for helpful comments.

REFERENCES

Atkinson, R.C., & Shiffrin, R.M. (1968). Human memory: A proposed system and its control processes. In K.W. Spence & J.T. Spence (Eds.), *The psychology of learning and motivation: Advances in research and theory* (Vol. 2, pp. 89–195). New York: Academic Press.

Baddeley, A.D. (1986). *Working memory*. Oxford: Clarendon Press.

Baddeley, A.D., Thomson, N., & Buchanan, M. (1975). Word length and the structure of short-term memory. *Journal of Verbal Learning and Verbal Behavior, 14*, 575–589.

Bjork, R.A., & Whitten, W.B. (1974). Recency-sensitive retrieval processes in long-term free recall. *Cognitive Psychology, 6*, 173–189.

Broadbent, D.E. (1958). *Perception and communication*. New York: Pergamon Press.

Carroll, J.B., Davies, P., & Richman, B. (1971). *The American Heritage word frequency book*. Boston: Houghton Mifflin.

Cowan, N. (1988). Evolving conceptions of memory storage, selective attention, and their mutual constraints within the human information processing system. *Psychological Bulletin, 104*, 163–191.

Cowan, N. (1992). Verbal memory span and the timing of spoken recall. *Journal of Memory and Language, 31*, 668–684.

Cowan, N., Day, L., Saults, J.S., Keller, T.A., Johnson, T., & Flores, L. (1992). The role of verbal output time in the effects of word length on immediate memory. *Journal of Memory and Language, 31*, 1–17.

Cowan, N., Keller, T., Hulme, C., Roodenrys, S., McDougall, S., & Rack, J. (in press). Verbal memory span in children: Speech timing clues to the mechanisms underlying age and word length effects. *Journal of Memory and Language*.

Crowder, R.G. (1989). Modularity and dissociations in memory systems. In H.L. Roediger & F.I.M. Craik (Eds.), *Varieties of memory and consciousness: Essays in honor of Endel Tulving* (pp. 271–294). Hillsdale, NJ: Erlbaum.

Crowder, R.G. (1993). Short-term memory: Where do we stand? *Memory & Cognition, 21*, 142–145.

Gardiner, J.M., & Gregg, V.H. (1979). When auditory memory is not overwritten. *Journal of Verbal Learning and Verbal Behavior, 18*, 705–719.

Glanzer, M., & Cunitz, A.R. (1966). Two storage mechanisms in free recall. *Journal of Verbal Learning and Verbal Behavior, 5*, 351–360.

Glenberg, A.M. (1984). A retrieval account of the long-term modality effect. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 10*, 16–31.

Greene, R.L. (1986a). A common basis for recency effects in immediate and delayed recall. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12*, 413–418.

Greene, R.L. (1986b). Sources of recency effects in free recall. *Psychological Bulletin, 99*, 221–228.

Nairne, J.S. (1992). The loss of positional certainty in long-term memory. *Psychological Science, 3*, 199–202.

(RECEIVED 5/15/93; REVISION ACCEPTED 11/1/93)