Reduction and elimination of format effects on recall

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Two experiments investigated whether the recall advantage of pictures and spoken words over printed words in working memory (Foos & Goolkasian, 2005; Goolkasian & Foos, 2002) could be reduced by manipulating letter case and sequential versus simultaneous presentation. Participants were required to remember 3 or 6 items presented in varied presentation formats while verifying the accuracy of a sentence. Presenting words in alternating uppercase and lowercase improved recall, and presenting words simultaneously rather than successively removed the effect of presentation format. The findings suggest that when forcing participants to pay attention to printed words you can make them more memorable and thereby diminish or remove any disadvantage in the recall of printed words in comparison with pictures and spoken words.

The present research integrates previous work with picture–word (Kosslyn, 1980; Paivio, 1975) and auditory–visual (Greene, 1985; Penney, 1989) comparisons by exploring why printed words are not recalled as well as other presentation formats (e.g., pictures and spoken words) (Foos & Goolkasian, 2005; Goolkasian & Foos, 2002). The experiments manipulate variables that are known to have an influence on the ease or difficulty of processing words to explore whether they could be effective at reducing or eliminating the recall disadvantage associated with printed words when a working memory task is studied. These experiments test the extent to which we can generalize a hypothesis developed in our previous work (Foos & Goolkasian, 2005) that if you force participants to pay attention to the printed words, their recall will improve and the effects of presentation format will diminish. In these studies, we refer to the advantage of spoken words and pictures over printed words as an effect of presentation format even though a change in modality is a part of the effect.

Earlier work that examined format differences in the visual modality found better memory for pictures than for words when explicit memory was tested (Goolkasian & Park, 1980; Paivio, 1975, 1978; Pellegrino, Rosinski, Chiesi, & Siegel, 1977; Smith & Magee, 1980) and in tests of implicit memory that ask for semantic information (e.g., asking participants to

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name members of some category) (McBride & Dosher, 2002; Wippich, Melzer, & Mecklenbräuker, 1998). Paivio's dual coding theory (1975) and Nelson's (1979) sensory–semantic model of encoding influenced this work and much of our later thinking with respect to picture–word differences. The differences obtained in these early studies were thought to be the result of encoding. Pictures may have dual codes (Paivio, 1975), more distinctive encoding, or more direct access to semantic coding (Nelson, 1979) in comparison to printed words.

Other early work examined auditory–visual modality differences. Better memory for auditory presentation, particularly for the last several items in a list, has been found (called the modality effect) (Cowan, Saults, Elliott, & Moreno, 2002; Gardiner, Gardiner, & Gregg, 1983; Greene, 1985; Greene, Elliott, & Smith, 1988) and has been shown to consist of sustained superiority for these auditory items and a brief advantage due to echoic storage that can be eliminated by other auditory input (i.e., the suffix effect; see Crowder, 1972; Goolkasian & Foos, 2002; Penney, 1989). The long-term modality effect takes place in long-term memory and is found for both serial and free recall (Cowan et al., 2002; Gardiner et al., 1983; Greene & Crowder, 1986).

Goolkasian and Foos (2002) examined retrieval from working memory and compared all three types of presentation using a dual task. These studies found little influence of format on the processing task but strong effects on item recall. Stimulus items presented as pictures and as spoken words are recalled (and recognized) equally well and better than printed words.

In several recent studies (Foos & Goolkasian, 2005) designed to uncover the source of these format effects, we varied the type and difficulty of the sentence verification task. These manipulations had no influence on the obtained format–modality differences. We hypothesized that the presentation format effect might lie in a disadvantage for printed words rather than different advantages for pictures (Nelson, 1979; Paivio, 1978) and spoken words (Penney, 1989). Attention paid to printed words may be attenuated because reading, for experienced readers, is to some extent automatic.

Some work has shown less conscious processing for printed words than for pictures (McBride & Dosher, 2002), and other work has shown that the alerting effect found for auditory stimuli (Posner, Nissen, & Klein, 1976) depends on the central allocation of attention and occurs for some visual as well as auditory stimuli (Turatto, Benso, Galfano, & Umiltà, 2002). To test this attention allocation hypothesis we required participants to articulate each of three or six presented items to ensure some allocation of conscious attention to all items. Results showed that performance with articulated printed words improved performance, whereas articulation had no influence on the recall of pictures and spoken words. In a second experiment we presented pictures, spoken words, and printed words under normal and degraded conditions, assuming that degradation would force more conscious attention to underattended printed words but have little influence on well-attended pictures and spoken words. Results again supported our attention allocation model in that degraded pictures and spoken words were recalled less well, whereas degraded printed words, particularly in the higher memory load condition, were recalled at a much higher level. The recall disadvantage of printed words lies in the fact that ordinarily they are not given full conscious attention, and forcing attention to printed words improved performance and diminished format effects.

Although it appears counterintuitive that making stimulus material more difficult to process can lead to benefits in recall, a number of studies (e.g., Tyler, Hertel, McCallum & Ellis, 1979) show similar effects. McDaniel, Ryan, and Cunningham (1989) showed that increasing the difficulty of encoding text material by deleting letters from words improved recall for both young and old participants. The need to actively generate letters during encoding improved recall, and there is a wealth of literature on such generation effects (e.g., Slamecka & Graf, 1978; Foos, Mora, & Tkacz, 1994). However, increasing difficulty during encoding does not always lead to better recall performance. In our previous study, degraded pictures and spoken words were recalled at lower levels than nondegraded stimuli. A theoretical context for our previous finding with degraded stimuli can be found in a series of studies by McDaniel and colleagues (McDaniel, Einstein, Dunay, & Cobb, 1986). They explained that making material difficult to encode will benefit recall only when it promotes active processing of information that would not have occurred through routine processing. Because our previous work found evidence of some attenuation of attention to items presented as printed words in comparison to pictures and spoken words, it is not surprising that requiring the participants to pay more attention to the printed words by articulating them or by degrading them resulted in better recall. Such a finding was not apparent with the other presentation formats because attention was already drawn to them.

In the present series, we manipulated variables that have been found to influence the ease of processing printed words. Our goal was to assess the extent to which these variables would influence the recall of printed words relative to the other presentation formats and thereby diminish the effect of presentation format. Testing each of these variables in our working memory task would help to outline the boundary conditions for our attention allocation hypothesis.

EXPERIMENT 1

Experiment 1 looked at whether the presentation of case-alternated words (e.g., *HoUsE*) would reduce the recall advantage of pictures and spoken words over printed words. We were interested in whether the additional effort needed to process case-alternated words over regular printed words would draw enough attention to the stimulus items to make them more memorable. Some prior work has found longer naming latencies for case-alternated words (Herdman, Chernecki, & Norris, 1999). Our previous work (Foos & Goolkasian, 2005) obtained such a bottom-up effect when we compared recall of degraded and normal printed words. However, the better recall of the degraded words was limited to long sequences of items. Support for the attention allocation hypothesis would be shown if case-alternated words were recalled better than ordinary printed words in our task.

The working memory task used in these experiments was a dual task taken from our previous work (Foos & Goolkasian, 2005). Figure 1 presents examples of the task components. The processing component was a sentence verification task that incorporated three kinds of problem-solving items: probability judgments with colors and with shapes and spatial relations between objects. After reading the sentence out loud, participants made an inference from two lines of background material containing visual objects. Performance on the processing task was recorded by measuring response time (RT) and accuracy for each sentence. The storage component required participants to store either three or six items presented as pictures, spoken words, or printed words (case-alternated and uppercase) and to free recall them at the end of a trial.

Two notable changes were made to the working memory task, however. First, a new pool of items was selected from two normed lists (Bonin, Peereman, Malardier, Meot, & Chalard, 2003; Rossion & Pourtois, 2004). Both lists were developed from students' ratings of concept familiarity and

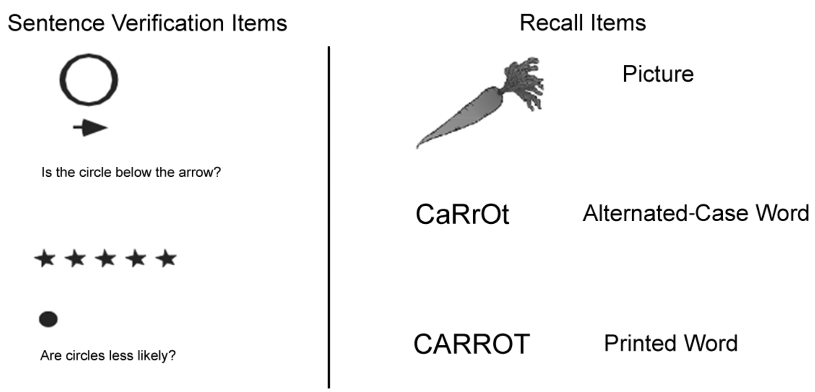

Figure 1. Examples of items used in the processing and storage components of the working memory task. Altered-case words were used only in Experiment 1

picture and name agreement. Second, although processing and storage components of the task were interleaved as in our previous work, their presentation order was reversed so that on each trial a storage item appeared first, followed by the sentence used in the processing task. This change was done to minimize the influence of recency effects on recall. The last item to appear on every trial was always the sentence used in the processing task rather than an item from the storage task. In the present experiment, items appeared in one of four presentation formats (picture, spoken word, printed words, and case-alternated words) and two list lengths (three and six). Format effects were expected to influence performance only on the recall task. RT and accuracy measures from the processing task were included to make sure that changes in performance on the recall task did not come at the cost of performance on the processing task.

METHOD

Participants

Twenty-six men and women student volunteers from the University of North Carolina at Charlotte participated in the experiment to obtain extra credit points toward their psychology class grade. Participation was restricted to those with normal (or corrected-to-normal) color vision.

Materials

The 36 items used in the recall task were taken from the items shown in the Appendix. They were chosen from two lists (Bonin et al., 2003; Rossion & Pourtois, 2004), based on ratings of familiarity and agreement between picture and mental image name. The items used in Experiment 1 and 2 were randomly selected from those rated as high and low, and in selecting items in both of the categories, we also made sure that there was name agreement between the picture and mental image name. Agreement was determined with an H measure (a statistical measure of name agreement, which varied from 0 [*perfect agreement*] to 1 [*no agreement*]), developed by Snodgrass and Vanderwart (1980). Items chosen for the two familiarity groups were equivalent, with high degrees of name agreement.

The items appeared as a picture, spoken word, alternated-case, and normal case printed word. Each picture was imported into Adobe Photoshop, and its size was adjusted to approximately 4 × 4 cm for use in all reported studies. When nouns appeared as printed words, they were printed with a Geneva font in a character size of 24 cpi. The normal case words were printed in uppercase, whereas the alternated-case words were created with alternating uppercase and lowercase letters. Half of the words started with uppercase letters and the remaining half lowercase. Figure 1 shows examples of alternated and normal case printed words. Spoken words were sound files created by a human female voice as a Macintosh system sound file.

Thirty-six stimuli, taken from our previous work (Foos & Goolkasian, 2005), were used in the processing task. Figure 1 presents some sample sentence verification items from the working memory task. As much as possible there were an equal number from the three kinds of problem-solving items: probability judgments with color and shape and spatial relations. Probability judgments with color used red, blue, yellow, and green squares that varied in number from one to seven and required the participant to make a judgment about whether a certain color was more or less likely. Probability judgments with shapes used stars, squares, circles, and triangles that varied in number from one to seven and required the participants to make a judgment about whether a shape was more or less likely. Spatial relation items presented two visual objects (star, arrow, square, and circle) and required participants to judge whether one object was below, on top of, or in another object. There were an equal number of the sentences with yes or no responses.

All stimuli were displayed in the center on a 15-inch Apple flat screen monitor. Stimulus presentation and data collection were controlled by SuperLab running on a Power Mac G4 computer.

Procedure

All participants were run individually in sessions of around 20 min. They were given five practice trials to familiarize themselves with the task. They were asked to read out loud the sentence as soon as it appeared and then to verify its accuracy while simultaneously remembering a number of items (for a total of three or six on each trial) presented in one of the four presentation format conditions. The storage and processing components of the task were interleaved. An item from the recall task appeared first for 1 s followed by a sentence, which the participant read out loud, and then the participant made a "yes–no" response using his or her left or right index finger. Articulation of the sentence has been shown to eliminate the sound advantage due to echoic memory when the preceding item is a spoken word (Goolkasian & Foos, 2002). A second item from the storage task followed the participant's response. After 1 s a second sentence appeared, followed by the third item from the recall task. In the long lists the sequence continued until six items appeared. A string of three question marks cued recall after presentation of the last sentence item. The participants called out as many of the items as they could remember in any order, and a research assistant recorded their spoken responses while the computer recorded the RTs and error rates from the sentence verification task. When ready, the participant used a key press to begin the next trial.

Two list lengths (three and six items) combined with four presentation formats (picture, spoken word, and normal and alternated-case printed word) resulted in eight experimental conditions, which were replicated three times for a total of 24 trials. Within each replication there was a random arrangement of presentation format and list length conditions.

The recall task used 36 items randomly drawn from the list presented in the Appendix, with the restriction that an equal number come from the high- and low-frequency categories. Items appeared once in each of the replications, and presentation format was always varied when an item was repeated. Stimulus items were randomly assigned to presentation format and list length conditions. Recall was scored as the proportion of items correctly remembered. Each of the 36 sentences for the processing task was used three times, once in each of the replications of the recall conditions.

RESULTS

Means were computed from the proportion of items correctly recalled and from correct RTs to the sentence verification for each participant across the three replications in each of the experimental conditions. Also recorded were the proportions of incorrect RT responses. Data from the recall, RTs, and errors were treated separately with a 4 × 2 repeated-measures analysis of variance (ANOVA) to test for presentation format and number of to-be-remembered items (i.e., three or six). The *F* tests that are reported in all of the experiments discussed in this report include the Greenhouse–Geisser correction to protect against possible violation of the homogeneity assumption.

Figure 2 presents the means from each of the experimental conditions. As in prior studies, recall was strongly influenced by presentation format and number of to-be-remembered items, $F(3, 75) = 51.83$, $p < .01$, $\eta^2 = .67$ and $F(1, 25) = 40.16$, $p < .01$, $\eta^2 = .62$. A series of within-participant comparisons (at the $p < .05$ level of significance) confirmed that alternated case (.51) significantly reduced inferiority of printed words (.40) to spoken words (.68) and to pictures (.61). Although pictures and spoken words resulted in better recall than printed words and alternated-case words, the effect of presentation format was significantly lower with case-alternated words. Recall rose 11% when printed words appeared in mixed case.

Presentation format was also found to interact with list length, $F(3, 75) = 5.11$, $p < .01$, $\eta^2 = .17$. Although a higher proportion of items were recalled with three rather than six to-be-remembered items, across all format conditions, there were differences in the size of the list length effect. The difference was larger with spoken words than in the other format conditions. For both short and long lists of to-be-remembered items, however, alternated-case words reduced format effects.

The RT data, in the middle panel of Figure 2, are trimmed means. Less than 3% of the RTs were longer than 6.5 s. An analysis showed small effects of presentation format, $F(3, 75) = 2.90$, $p < .04$, $\eta^2 = .10$, and list length, $F(1, 25) = 8.05$, $p < .01$, $\eta^2 = .24$ but no interaction, $F < 1$. Participants responded to the sentences more rapidly when long (3,175 ms) as compared to short (3,272 ms) sequences were stored and when pictures rather than the other format conditions were used.

Errors in the processing task were also found to vary with format conditions, $F(3, 75) = 7.42$, $p < .01$. More errors were made when printed words (.11) or spoken words (.09) were used than in the picture (.05) or the

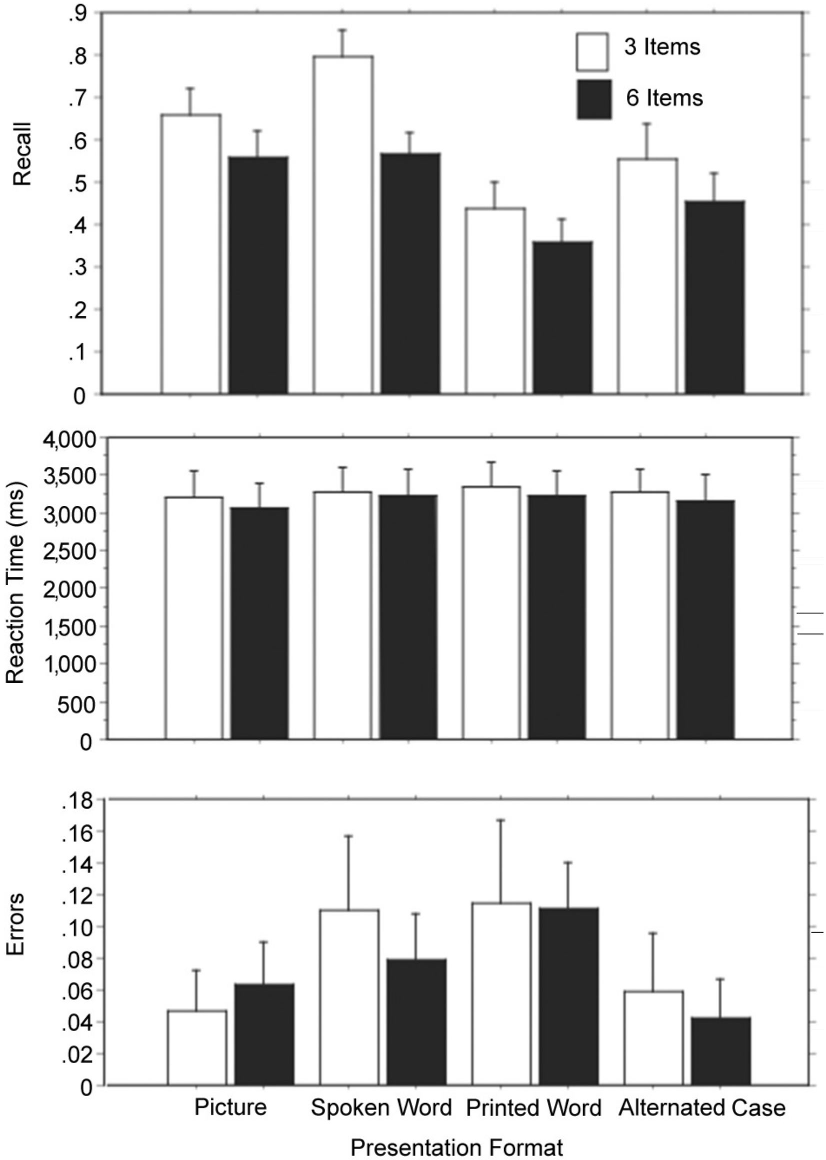

Figure 2. Mean scores for the format × list length interaction, Experiment 1. Error bars represent 95% confidence intervals. The top panel presents the proportion of items recalled in the storage task, and the middle panel presents the reaction times from the sentence verification task. The bottom panel presents the proportion of errors made in the sentence verification task

alternated-case word (.05) condition. None of the other effects in the analysis of the errors reached significance.

DISCUSSION

As predicted, alternating the case of the letters in a word improved recall of those words in comparison to printed words presented in only uppercase letters. The advantage of pictures and spoken words was reduced by 11%. This finding supports the allocation of attention hypothesis formulated in our previous work. Forcing more conscious attention to printed words, by presenting them in alternating case, improved recall.

One might wonder whether the improved performance with alternating-case words could be due to distinctiveness. Perhaps those items were encoded more distinctively than ordinary words, although not more distinctively than pictures or spoken words. We recognize this possibility but regard it as unlikely because the time spent processing each presented item was so brief. Furthermore, the fact that other such manipulations designed to draw attention to printed words were also used with pictures and spoken words (e.g., articulation and degradation) and showed the same result makes distinctive encoding as a reason for the improved performance somewhat unlikely.

The small effects of presentation format on the speed and accuracy of the processing task were not related to the recall of the alternated-case words. Those effects were focused primarily on faster processing with pictures and more errors with spoken and printed words. Also, this finding was not a general pattern across these experiments or in the earlier published works.

In general, the findings were consistent with our previous work (Foos & Goolkasian, 2005). Using a new item pool and reversing the order of the working memory task by starting with a recall item and ending with the sentence verification task did not change the strong effect of presentation format. Overall performance in the recall task dropped about 5% in comparison with our previous work. This is probably because participants could no longer recall the last item as easily as they had in previous work when the presentation order of the dual task was reversed. This reduction in recall was consistent across all format and list length conditions. We also noticed some minor intrusions in the recall task from the visual objects presented as background in the processing task.

EXPERIMENT 2

In Experiment 2, we again used four presentation format conditions, but this time picture and spoken words were compared with printed words presented one at a time, as in the previous experiments, or all at once in a list format. Figure 3 provides an example of how the printed words were interleaved with a sentence from the processing task in each of the printed word conditions. It is important to emphasize that even though there were differences in the number of times each printed word appeared in the simultaneous and sequential printed word conditions, the total amount of time provided for processing the items in the storage task remained constant for all four presentation format conditions.

Presenting the three or six to-be-remembered items simultaneously rather than in a serial manner required participants to consciously allocate the limited processing time (1 s per item) flexibly across the three or six items per trial. Order of words in the simultaneous condition was held constant on each trial so that participants could have the opportunity to take advantage of the spatial layout when allocating attention to the items rather than spending time searching for specific items. A number of researchers have suggested that simultaneous rather than sequential visual presentations may be more comparable to auditory presentations for short-term memory performance (Penney, 1975; Kahneman & Henik, 1977). Frick (1985) compared simultaneous and sequential presentations of letters in a short-term memory task and found more interference effects with simultaneous rather than successive presentation. These differences suggested that visual short-term memory was engaged only when items appeared simultaneously.

An especially relevant series of studies (Conway & Christiansen, 2005; Saffran, 2002) investigated sensory modality differences in processing sequential input through a statistical learning artificial grammar paradigm. Patterns of sounds, words, and finger vibrations with predictive relationships were used as stimuli, and participants' use of the statistical information was compared across modalities. Although these studies were designed to

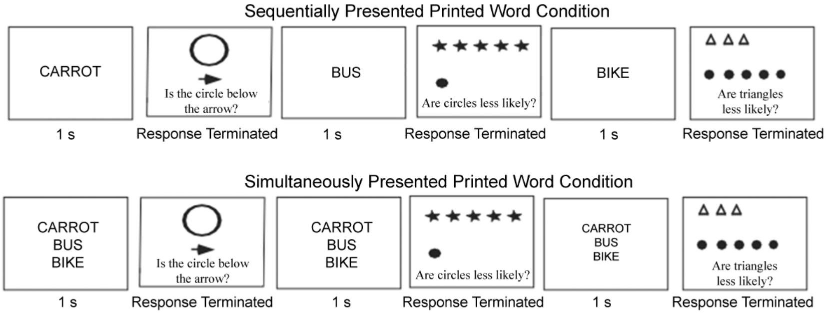

Figure 3. Comparison of how the stimuli from the two tasks were interleaved in the sequential and simultaneous printed word condition, Experiment 2

investigate how learners discover structure in linguistic material, there were similar learning outcomes whether linguistic or nonlinguistic materials were used (Saffran, 2002; Saffron, Johnson, Aslin, & Newport, 1999). With sequential input, there was a learning advantage with auditory as compared to visual or tactile presentation techniques, and the advantage was obtained primarily in the final part of the input sequence (Conway & Christiansen, 2005). With visual presentation, however, simultaneous presentation was most beneficial (Saffran, 2002). Evidence from these studies suggests that to improve memory for visually presented sequences, it might be important to present the stimulus material all at once rather than one by one.

Experiment 2 tested this hypothesis by comparing recall from working memory of four presentation formats: pictures, spoken words, printed words presented sequentially, and printed words presented simultaneously. Because simultaneous presentation allows the participant to allocate attention to any or all items, the allocation of attention model predicts greatly reduced format effects for this condition when compared with sequentially presented words. With serial lists, participants receive the items one by one and have to process each item in turn. However, with simultaneous presentation the participant has conscious control of how to use the limited study time and must actively decide how to allot his or her time across the items. Perhaps even the list presentation itself may be more attention getting than items presented one at a time.

METHOD

Twenty-seven men and women drawn from the same pool as the previous experiment participated in the study. These students were not the same as the participants in the other experiment. Materials were the same as Experiment 1. There were four presentation format conditions (picture, spoken word, printed words, and simultaneous printed words) and two list lengths (three and six). This experiment differed from Experiment 1 by replacing the alternated-case format condition with one in which the printed words were presented in a list and the list was interleaved three or six times with the items from the processing task. All participants were run individually in sessions of around 20 min. The procedure was the same as in the previous experiments. Participants read the sentence out loud as soon as it appeared and then verified its accuracy while simultaneously remembering up to three or six items.

RESULTS

Data from the 27 participants were analyzed with a 4×2 repeated-measures ANOVA. Figure 4 presents the means from each of the experimental conditions. As in prior studies, recall was strongly influenced by presentation format and number of to-be-remembered items, $F(3, 78) = 65.98$, $p < .01$, $\eta^2 = .72$ and $F(1, 26) = 145.66$, $p < .01$, $\eta^2 = .85$. A series of within-participant contrasts (at the $p < .05$ level of significance) within the format main effect confirmed that recall of printed words with simultaneous presentation (.71) was significantly better than printed words presented one at a time (.42) and better than pictures (.63). Presentation format was also found to interact with list length, $F(3, 78) = 15.40$, $p < .01$, $\eta^2 = .37$. Although a higher proportion of items were recalled with three rather than six to-be-remembered items across all format conditions, there were some differences in the size of the format effect. As in Experiment 1, format effects were larger in short than long lists of items. For both short and long lists of to-be-remembered items, however, the recall of printed words presented simultaneously was comparable to that of spoken words.

The RT data, in the middle panel of Figure 4, are trimmed means. Less than 1.5% of the RTs were longer than 6.5 s. An analysis showed small effects of presentation format, $F(3, 78) = 5.72$, $p < .01$, $\eta^2 = .18$ (means for the picture, spoken word, printed word, and simultaneous printed word conditions were 3,248, 3,332, 3,449, and 3,306 ms, respectively), and list length, $F(1, 26) = 11.16$, $p < .01$, $\eta^2 = .30$ (means for the short and long lists were 3,376 and 3,291 ms, respectively). There was also a significant interaction, $F(3, 78) = 3.33$, $p < .02$, $\eta^2 = .11$. Responses to the sentences were more rapid when long as compared to short sequences were stored but only when pictures and sequential printed words were stored. For the other two format conditions (spoken words and simultaneous printed words), there was no effect of list length.

Errors represented less than 6.5% of the responses made in the processing task. The lower panel of Figure 4 presents the average proportion of errors by experimental condition. These data were not found to vary with format conditions, $F(3, 78) = 1.81$, $p = .15$, with list length, $F(1, 26) = 1.54$, $p = .23$, or with the interaction of format by list length, $F(3, 78) = 1.14$, $p = .34$.

DISCUSSION

Changing the presentation of the printed words from sequential to a simultaneous list format significantly improved recall and eliminated the recall advantage associated with pictures and spoken words. With both recall and RTs, the spoken word and the simultaneous printed word conditions produced comparable data. Printed words were recalled at some disadvantage to pictures and spoken words only when they were presented in a sequential list. Permitting the participants the flexibility to consciously

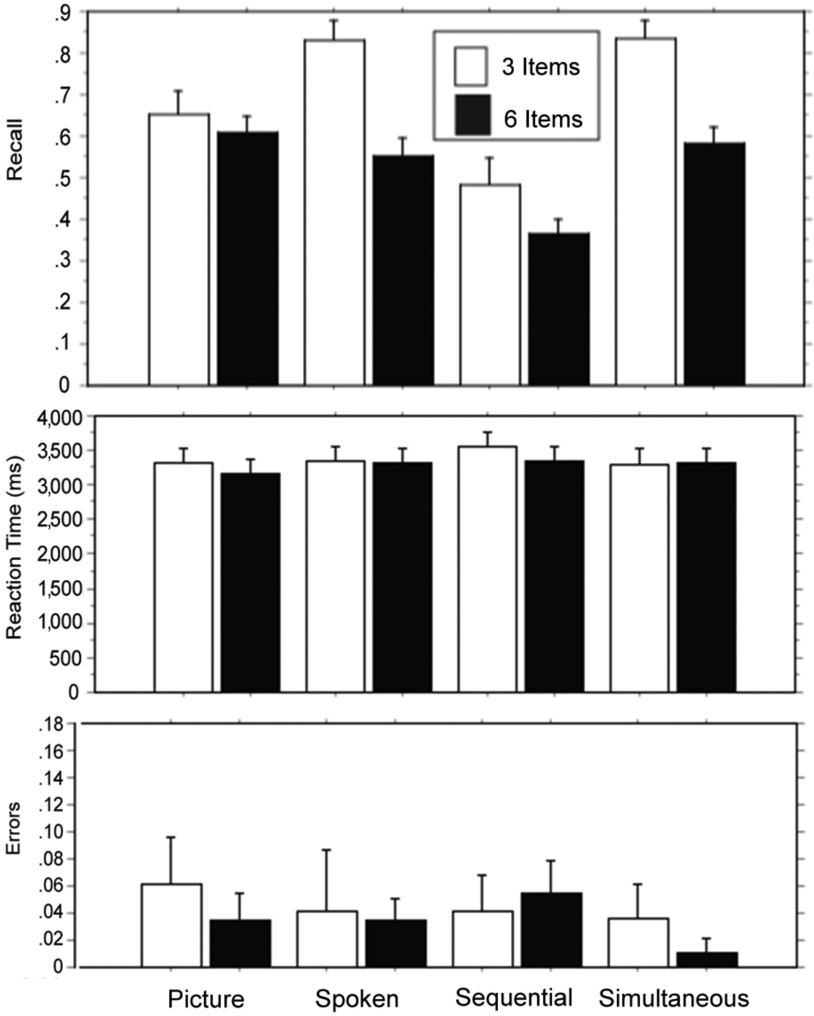

Figure 4. Mean scores for the format × list length interaction, Experiment 2. Error bars represent 95% confidence intervals. The top panel presents the proportion of items recalled in the storage task, and the middle panel presents the reaction times from the sentence verification task. The bottom panel presents the proportion of errors made in the sentence verification task

allocate their attention to any one of the to-be-recalled items during the limited presentation time was sufficient to eliminate the recall advantage of pictures and spoken words over printed words found in past research with this working memory task (Foos & Goolkasian, 2005; Goolkasian & Foos, 2002).

The findings of these two experiments replicate numerous prior studies showing an advantage of pictures (Nelson, 1979; Paivio, 1978) and spoken words (Penney, 1989) over printed words and in a working memory task (Foos & Goolkasian, 2005; Goolkasian & Foos, 2002). Although a new set of items were used in the recall task and there was a reversal in the presentation order of the two components of the working memory task, the same strong effects of presentation format were obtained in each of the experiments.

The results from these experiments focus on conscious attention to encoding as pivotal in producing some of the known effects of presentation format. Whether printed words are compared with pictures or spoken words, presentation format effects are significantly lower when more conscious processing is devoted to printed words. To accommodate these findings into our attentional allocation hypothesis, we would have to add some depth to our notion and suggest that it is not just a matter of forcing attention to the printed words. Although recall of printed words is improved with the addition of forced attention, it is the enhanced conscious processing that results in better memory. This was particularly true when printed words were presented simultaneously. In this case, the flexible allocation of attentional resources to the list of three or six to-be-remembered items made it comparable to the recall of spoken words and pictures.

Are there alternative explanations for this latter finding? One might argue that the retention interval is shorter for simultaneous presentation because all items are presented the last time, whereas with successive presentation items are presented only once. With sequential presentation, items presented first have a longer retention interval than items presented last. Of course, total presentation time and average retention interval are equal for all items presented sequentially or simultaneously. Furthermore, several studies in the past (Keppel & Underwood, 1962; Reitman, 1974) have shown that forgetting over such short retention intervals is not really a function of retention interval. Forgetting is largely due to the buildup of proactive interference from preceding and similar items. In the present case, where items come from a number of different categories (e.g., animals, body parts, buildings, food, furniture, occupations, tools, transportation) the buildup of proactive interference is most unlikely (Wickens, 1972). In short, retention intervals, as well as total exposure time, are the same on average, and items are so different that any significant buildup of proactive interference is unlikely.

Perhaps participants' certainty as to the number of items being presented on a given trial is a factor. In the sequential condition, participants see only one item at the beginning of a trial and are unsure of the total number of to-be-remembered items until after the third item on that trial (i.e., when one next receives the recall signal or a fourth item telling the participant that six items will be presented), whereas in the simultaneous condition all three or six items are presented immediately. This brief difference in uncertainty (over the first three items) seems to us unlikely to account for the obtained effect. Before the experimental trials begin, the practice trials inform participants that three or six items will always occur. Knowing which will occur on a particular trial a few seconds earlier (as in the case of simultaneous presentation) seems of minor benefit.

The present finding is consistent with other research that compares performance across auditory and visual modalities. We have known for some time that there are basic differences in the way in which sense modalities respond to stimulus characteristics. However, we know that any explanation of format effects must deal with the findings that both pictures (visual presentation) and spoken words (auditory presentation) produce better performance than printed words (visual presentation). Therefore, such results cannot be explained as simple auditory–visual differences. Manipulations that draw conscious attention to printed words reduce format effects by improving performance with ordinarily underattended printed words. However, the present findings suggest that an even easier way of improving the recall of printed words is using simultaneous presentation and allowing participants to flexibly allocate their attention.

When taken together these findings show effects of presentation format on working memory and help identify a principle to guide efficient processing of and memory for stimulus information. The findings extend a hypothesis generated in our previous work (Foos & Goolkasian, 2005) that when you force participants to pay attention to printed words you can make them more memorable and thereby diminish or remove any disadvantage in the recall of printed words in comparison to pictures and spoken words. The fact that support for the attention allocation hypothesis was found in the findings from both experiments suggests that the locus of the effect is on factors that influence conscious attention to the presented stimuli. Presenting the words in mixed case improved recall by 11%, and presenting the printed words simultaneously, rather than successively, eliminated the format effect entirely.

These conclusions are limited by the nature of the presentation conditions under study. It is hard to say whether the effects of presentation format would be reduced when participants are allowed more time to process the to-be-remembered material or when more permanent memory is tested.

Appendix. Recall task items

Banana	Knife	Alligator	Caterpillar
Bed	Lamp	Bear	Helmet
Bike	Leg	Cannon	Lobster
Bottle	Pants	Harp	Giraffe
Bowl	Refrigerator	Raccoon	Maze
Bus	Ring	Well	Axe
Car	Ruler	Zebra	Grasshopper
Carrot	Saltshaker	Tank	Wagon
Cat	Sandwich	Fairy	Windmill
Doorknob	Tomato	Hook	Fox
Finger	Toothbrush	Barrel	Horn
Fork	Tree	Sword	Boomerang
Hanger	Umbrella	Mermaid	Handcuffs
Key		Accordion	

Note

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References

Bonin, P., Peereman, R., Malardier, N., Meot, A., & Chalard, M. (2003). A new set of 299 pictures for psycholinguistic studies: French norms for name agreement, image agreement, conceptual familiarity, visual complexity, image variability, age of acquisition, and naming latencies. *Behavior Research Methods, Instruments, & Computers, 35,* 158–167.

Conway, C. M., & Christiansen, M. H. (2005). Modality-constrained statistical learning of tactile, visual, and auditory sequences. *Journal of Experimental Psychology: Learning Memory, and Cognition, 31,* 24–39.

Cowan, N., Saults, J. S., Elliott, E. M., & Moreno, M. (2002). Deconfounding serial recall. *Journal of Memory and Language, 46,* 153–177.

Crowder, R. G. (1972). Visual and auditory memory. In J. F. Kavanaugh & I. G. Mattingly (Eds.), *Language by ear and by eye: The relations between speech and learning to read* (pp. 251–275). Cambridge, MA: MIT Press.

Foos, P. W., & Goolkasian, P. (2005). Presentation format effects in working memory: The role of attention. *Memory & Cognition, 33,* 499–513.

Foos, P. W., Mora, J. J., & Tkacz, S. (1994). Student study techniques and the generation effect. *Journal of Educational Psychology, 86,* 567–576.

Frick, R. W. (1985). Testing visual short term memory: Simultaneous versus sequential presentations. *Memory & Cognition, 13,* 346–356.

Gardiner, J. M., Gardiner, M. M., & Gregg, V. H. (1983). The auditory recency advantage in longer term free recall is not enhanced by recalling prerecency items first. *Memory & Cognition, 11,* 616–620.

Goolkasian, P., & Foos, P. W. (2002). Presentation format and its effect on working memory. *Memory & Cognition, 30,* 1096–1105.

Goolkasian, P., & Park, D. C. (1980). Processing of visually presented clock times. *Journal of Experimental Psychology: Human Perception and Performance, 6,* 707–717.

Greene, R. L. (1985). Constraints on the long-term modality effect. *Journal of Memory and Language, 24,* 526–541.

Greene, R. L., & Crowder, R. G. (1986). Recency effects in delayed recall of mouthed stimuli. *Memory & Cognition, 14,* 355–360.

Greene, R. L., Elliott, C. L., & Smith, M. D. (1988). When do interleaved suffixes improve recall? *Journal of Memory and Language, 27,* 560–571.

Herdman, C. M., Chernecki, D., & Norris, D. (1999). Naming case alternated words. *Memory & Cognition, 27,* 254–266.

Kahneman, D., & Henik, A. (1977). Effects of visual grouping on immediate recall and selective attention. In S. Dornic (Ed.), *Attention and performance VI* (pp. 307–332). Hillsdale, NJ: Erlbaum.

Keppel, G., & Underwood, B. J. (1962). Proactive inhibition in short-term retention of single items. *Journal of Verbal Learning and Verbal Behavior, 1,* 153–161.

Kosslyn, S. M. (1980). *Image and mind.* Cambridge, MA: Harvard University Press.

McBride, D. M., & Dosher, B. A. (2002). A comparison of conscious and automatic memory processes for picture and word stimuli: A process dissociation analysis. *Consciousness and Cognition, 11,* 423–460.

McDaniel, M. A., Einstein, G. O., Dunay, P. K., & Cobb, R. E. (1986). Encoding difficulty and memory: Toward a unifying theory. *Journal of Memory and Language, 25,* 645–656.

McDaniel, M. A., Ryan, E. B., & Cunningham, C. J. (1989). Encoding difficulty and memory enhancement for young and older readers. *Psychology and Aging, 4,* 333–338.

Nelson, D. L. (1979). Remembering pictures and words: Appearance, significance, and name. In L. S. Cermak & F. I. M. Craik (Eds.), *Levels of processing in human memory* (pp. 45–76). Hillsdale, NJ: Erlbaum.

Paivio, A. (1975). Perceptual comparisons through the mind's eye. *Memory & Cognition, 3,* 635–647.

Paivio, A. (1978). A dual coding approach to perception and cognition. In H. L. Pick & E. Saltzman (Eds.), *Modes of perceiving and processing information* (pp. 39–51). Hillsdale, NJ: Erlbaum.

Pellegrino, J. W., Rosinski, R. R., Chiesi, H. L., & Siegel, A. (1977). Picture–word differences in decision latency: An analysis of single and dual memory models. *Memory & Cognition, 5,* 383–396.

Penney, C. G. (1975). Modality effects in short-term verbal memory. *Psychological Bulletin, 82,* 68–84.

Penney, C. G. (1989). Modality effects and the structure of short-term verbal memory. *Memory & Cognition, 17,* 398–422.

Posner, M. I., Nissen, M. J., & Klein, R. M. (1976). Visual dominance: An information-processing account of its origins and significance. *Psychological Review, 83,* 157–171.

Reitman, J. S. (1974). Without surreptitious rehearsal, information in short-term memory decays. *Journal of Verbal Learning and Verbal Behavior, 13,* 365–377.

Rossion, B., & Pourtois, G. (2004). Revisiting Snodgrass and Vanderwart's object pictorial set: The role of surface detail in basic-level object recognition. *Perception, 33,* 217–236.

Saffran, J. R. (2002). Constraints on statistical language learning. *Journal of Memory and Language, 47,* 172–196.

Saffran, J. R., Johnson, E. K., Aslin, R. N., & Newport, E. L. (1999). Statistical learning of tone sequences by human infants and adults. *Cognition, 70,* 27–52.

Slamecka, N. J., & Graf, P. (1978). The generation effect: Delineation of a phenomenon. *Journal of Experimental Psychology: Human Learning and Memory, 4,* 592–604.

Smith, M. C., & Magee, L. E. (1980). Tracing the time course of picture–word processing. *Journal of Experimental Psychology: General, 109,* 373–392.

Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory, 6,* 174–215.

Turatto, M., Benso, F., Galfano, G., & Umiltà, C. (2002). Nonspatial attention shifts between audition and vision. *Journal of Experimental Psychology: Human Perception and Performance, 28,* 628–639.

Tyler, S. W., Hertel, P. T., McCallum, M. C., & Ellis, H. (1979). Cognitive effort and memory. *Journal of Experimental Psychology: Human Learning and Memory, 5,* 607–617.

Wickens, D. D. (1972). Characteristics of word encoding. In A. W. Melton & E. Martin (Eds.), *Coding processes in human memory* (pp. 191–215). New York: Winston.

Wippich, W., Melzer, A., & Mecklenbräuker, S. (1998). Picture or word superiority effects in implicit memory: Levels of processing, attention, and retrieval constraints. *Swiss Journal of Psychology, 57,* 33–46.