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Artificially induced valence of distractor words increases the effects of irrelevant speech on serial recall

AXEL BUCHNER and BETTINA MEHL
Heinrich-Heine-Universität, Düsseldorf, Germany

KLAUS ROTHERMUND
Friedrich-Schiller-Universität, Jena, Germany

and

DIRK WENTURA
Universität des Saarlandes, Saarbrücken, Germany

In a game context, nonwords either were artificially associated with negative valence or were in some sense neutral or irrelevant. Subsequently, participants memorized target words in silence or while attempting to ignore the negatively valent, irrelevant, or neutral auditory distractor nonwords. The presence of distractor nonwords impaired recall performance, but negative distractor nonwords caused more disruption than neutral and irrelevant distractors, which did not differ in how much disruption they caused. These findings conceptually replicate earlier results showing disruption due to valence with natural language words and extend them by demonstrating that auditory features that may possibly be confounded with valence in natural language words cannot be the cause of the observed disruption. Explanations of the irrelevant speech effect within working memory models that specify an explicit role of attention in the maintenance of information for immediate serial recall can explain this pattern of results, whereas structural models of working memory cannot.

Recently, evidence showing that nonacoustic features of auditory distractors affect serial recall performance has mounted. Neely and LeCompte (1999) have demonstrated that the semantic similarity between targets and distractors may play a role in serial recall performance. Buchner and Erdfelder (2005) have shown that the frequency of auditory distractor words may affect the serial recall of visually presented words, in that rare words cause more disruption than frequent words. Finally, Buchner, Rothermund, Wentura, and Mehl (2004) have reported that both positively and negatively valent distractor words caused more disruption of serial recall performance than neutral distractors, and negative distractors caused more disruption than positive distractors.

In short, these results are problematic for current versions of both the *modular working memory model* (Baddeley & Logie, 1999) and the *object-oriented episodic record model* (Jones, 1993) because these models imply that only acoustic distractor features may affect serial recall performance. In contrast, these results are compatible with the *integrated memory-and-attention framework* suggested by Cowan (1999) as well as the *feature model* (Nairne, 1990; Neath, 2000) because these models allow for attention to play a role in the maintenance of information in short-term memory. Any distractor property that increases attentional distraction may therefore impair serial recall performance.

More specifically, within the modular working memory model the preferred strategy for the immediate serial recall of short, visually presented word lists is to convert the words into a phonological representational format for maintenance rehearsal in the limited-capacity articulatory loop module. Auditory distractor words automatically gain access to this store and compete with the target representations, thereby impairing recall performance (Salamé & Baddeley, 1982). Thus, the impairment occurs in a working memory module defined by its phonological representational format, which is why nonphonological properties such valence, word frequency, or semantic content of distractors cannot directly affect serial recall. Critically, the component identified with attentional function is the so-called central executive, which is "not involved in temporary storage" (Baddeley & Logie, 1999, p. 28). Thus, the temporary maintenance of words cannot be affected by manipulations of attention. The situation is similar for the object-oriented episodic record model (Jones, 1993). In this model, the crucial process in imme-

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diate serial recall is that of seriation of the to-be-recalled objects, which are "linked" by a series of production rules. Temporary representations of to-be-recalled visual items (the to-be-remembered targets in the present case) and the links interconnecting them are constructed by means of articulation. An auditory stream is parsed into objects (the distractors in the present case) by preattentive segmentation processes. The number of changing states in the auditory signal (roughly defined as rapid changes in frequency and amplitude) determines the number of objects that will be formed (up to a limit). Additional links are established automatically among auditory distractor objects. The process of seriation along these additional links competes with the seriation of the mutually linked visual targets. This competition may cause the loss of the link to a target, which would then be unavailable for recall. Nonacoustic distractor properties such as valence, word frequency, or semantic content cannot affect the changing-state-based formation of the auditory objects and thus must not affect serial recall.

In contrast, any distractor property that attracts attention may affect working memory performance within Cowan's (1999) memory-and-attention framework. Here, working memory is defined by the set of cognitive processes needed to retain memory representations in a highly accessible state. The most highly activated working memory elements represent the focus of attention. In immediate recall tasks, the focus of attention comprises the to-be-recalled targets. The activation of a target's representation may be reduced if task-irrelevant stimuli attract attention. Loss of activation reduces the probability of successful recall of the target. It is known that in Stroop tasks, valent words delay the naming of the color in which they are printed more than neutral words do. This has been interpreted to show that valent words attract attention at the expense of resources available to other cognitive processes (McKenna & Sharma, 1995; Pratto & John, 1991; Williams, Mathews, & MacLeod, 1996; see also Algom, Chajut, & Lev, 2004; McKenna & Sharma, 2004). Similarly, valent auditory distractors may attract more attention than neutral auditory distractors at the expense of resources available for serial recall. Therefore, nonphonological distractor properties may affect serial recall in that valent distractors may impair performance more than neutral distractors do. The feature model (Nairne, 1990; Neath, 2000) allows similar predictions because it includes an attentional parameter that reflects the amount of processing resources available for the primary memorization tasks. If competing processes, such as orienting toward auditory distractors, required attentional resources to a greater or lesser degree, then short-term memory might also be disrupted to a greater or lesser degree.

Buchner et al. (2004) found more disruption by valent than by neutral auditory distractor words; this finding favors models that explicitly allow for a role for attention over models that do not. To our knowledge, the observed effects of distractor valence on serial recall performance are unique, which is why a conceptual replication of those experiments seemed highly desirable. This was an important purpose of the experiment reported here. We also wanted to assess a possible objection to the original interpretation of those valence effects. Distractor valence was manipulated using natural language words. Obvious confounding variables such as number of syllables, spoken word length, concreteness, and word frequency were carefully controlled. However, natural language words always carry the risk that an as yet undetected variable is confounded with the experimental manipulation. Considering that acoustic profiles of utterances differ for different emotional expressions (Banse & Scherer, 1996), one could speculate that negative words such as *aggressive* may differ subtly in their articulation (e.g., fundamental frequency, vocal energy, energy envelope) from neutral words such as *wearisome*. These potential differences might also be related to phonological variables such as the number of perceptible changing states, an auditory distractor property that is known to affect serial recall (Jones, 1993). If this were indeed the case, then we could no longer be sure that the increased disruption caused by negative distractor words in comparison with that caused by neutral words was indeed due to distractor valence. Although we have no direct evidence suggesting that such a confounding variable played a role, the mere suspicion that it might have done so suggested that we test whether or not valence effects could still be observed when such confounding variables definitely could not play a role.

We therefore tried to replicate our earlier findings using meaningless nonwords. In the first phase of the experiment, these nonwords were artificially associated with negative valence or were in some sense neutral or irrelevant. More precisely, participants classified nonwords according to their final consonant. Nonwords were categorized into three different types according to the vowels they contained. Participants learned that if they did not respond quickly and correctly to one type of nonwords (henceforth, *negative* nonwords), their "gaming score" would suffer badly. Participants also learned that there was no time pressure for responding to a second type of nonwords (henceforth, *neutral* nonwords) and that correct or incorrect responses would result in small gains and losses, respectively. A third type of nonwords did not require any response at all (henceforth, *irrelevant* nonwords).

In a second phase of the experiment during which participants performed a serial recall task, the three types of nonwords were used as auditory distractors. A successful replication of the results of Buchner et al. (2004) would entail the observation of impaired serial recall performance with valent distractors but not with neutral or irrelevant distractors. In addition to eliminating possible confounds of distractor type with phonological qualities, the present experiment allowed us to test whether behavioral relevance, or perhaps simple stimulus–response associations, played a role in the amount of distraction from the serial recall task. Neutral nonwords shared with negative nonwords the property of being associated with a specific response, whereas irrelevant words were simply heard and never required an overt response. Thus, if the attention-grabbing power of distractors depended on simple response associations, then serial recall performance would be worse for neutral than for irrelevant distractor words because only the former were associated with a response. If, in contrast, behavioral relevance in a more general sense is decisive in that it refers to compulsorily orienting toward a behaviorally relevant signal—a danger signal in the present case—then serial recall performance would be worse for negative than for neutral distractor words, because only the former were associated with a possible big loss in case of a slow or incorrect response. Note that positive stimuli or stimuli associated with a current concern of a participant could perhaps be as distracting as a negative stimulus. We decided to focus on the contrast of negative stimuli versus neutral and irrelevant stimuli simply because negative words had the strongest potential to disrupt performance in the experiments reported by Buchner et al. (2004).

In Experiment 1 of Buchner et al. (2004), we had used lists of six to-be-recalled three-syllable words. With such long lists (18 syllables in total), an increasing probability of positional confusion may have made recall of items at later serial positions particularly difficult, with the exception of the last item, for which the final serial position served as a convenient anchor. An informal inspection of spoken recall protocols from our lab suggested that participants often focused on the first, second, third, and final words, skipping the intermediate words. This strategy seemed to occur more frequently when distractors were present, which made recall much more difficult than in the silent control condition.

Such a distractor-specific strategy shift would have several unwanted consequences. First, the difference between the silent control and the distractor conditions would be confounded by a strategy shift. Second, the serial recall performance measure would be less sensitive to differences among distractor conditions because of a floor effect at Serial Positions 4 and 5 in the distractor conditions. Third, a performance drop at Serial Positions 4 and 5, together with a performance increase at the final position that was more pronounced for the distractor conditions than the silent control condition, would facilitate finding a statistical interaction between the serial position and distractor condition variables. This could have important theoretical implications. Buchner et al. found such an interaction and judged it to be problematic for the feature model (Nairne, 1990; Neath, 2000), because the mechanism by which the feature model explains the effect of irrelevant auditory distractors on serial recall does not predict such an interaction. Features of the irrelevant sounds are assumed to overwrite some elements of the feature vectors of the target representations in working memory, causing these representations to become even more degraded and less likely to be recalled than they normally would be. Feature overwriting occurs irrespective of the target's serial position. Thus, irrelevant speech must reduce recall performance uniformly across all serial positions, thereby precluding a serial position × distractor type interaction. However, if such an interaction were due to a strategy shift, then it would not speak against the interference mechanism posed by the feature model. A more reasonable test of the feature model would therefore require shorter target sequences for which strategy shifts were not expected.

Given these considerations, we decided to use lists of four target words rather than six as in Buchner et al. (2004). However, as in those experiments, six distractors were displayed in the auditory distractor conditions: Distractors 1–4 were presented in parallel to the four visual targets. Distractors 5 and 6 filled the subsequent 1,200-msec retention interval. The timing was identical for the silent control condition.

METHOD

Participants

The participants were 46 students (31 women) who were paid for their participation. Their ages ranged from 19 to 58 years (M = 26 years). Each participant was tested individually.

Materials

The participants wore headphones that were plugged directly into an Apple iMac computer, which controlled the experiment. Sounds were produced at a level of about 75 dB(A).

Three types of three-syllable nonwords were used as auditory targets in the valence induction phase and as distractors in the serial recall phase of the experiment. For one type of nonwords, three *a* vowels were connected by adding different consonants after the vowels, with the restrictions that the nonwords' final consonant had to be *l* or *z* and that neither *l* nor *z* was allowed in any other position. The resulting nonword (e.g., *adabal*) was duplicated, and the terminal consonant in the duplicate nonword was replaced by the letter *z* (e.g., *adabaz*). Seven such pairs were constructed. Two more types of 14 nonwords were created by replacing, in each word of the first type, the vowel *a* with the vowel *e* (e.g., *edebel*) and the vowel *o* (e.g., *odobol*), respectively. All nonwords used in the experiment are listed in the Appendix. The nonwords were spoken by a female voice, digitally recorded at 44.1 kHz using 16-bit encoding, edited to last 600 msec each, and normalized to minimize amplitude differences among the words.

The target words to be memorized during the serial recall phase were the same seven three-syllable German nouns as in Buchner et al. (2004): *Bilderbuch* (picture book), *Hutschachtel* (hat box), *Kalender* (calendar), *Laterne* (lantern), *Obstschale* (fruit bowl), *Kartoffel* (potato), and *Tannenbaum* (fir tree). They were used for all experimental conditions. For every experimental sequence, four of these seven words were sampled randomly without replacement for presentation.

Procedure

The experiment consisted of two phases: a valence induction phase and a serial recall phase. The valence induction phase consisted of 168 consonant judgment trials. The serial recall phase consisted of eight blocks, each of which consisted of 42 consonant judgment trials followed by 8 serial recall trials. Each participant began with a fictitious score of 1,000 points and knew that this score could be increased or decreased on the basis of his or her performance on the consonant judgment trials that made up the valence induction phase and that were also presented between serial recall trials within the serial recall phase.

Each trial in the consonant judgment task required the participants to decide whether the final consonant of an auditory nonword was *l* or *z* and then press the appropriate response key. The participants learned that there were three types of auditory nonwords (see the Materials section), classified according to their vowel: *a*, *e*, or *o*.

An example of a consonant judgment task follows. In this task, nonwords constructed with the vowel *a* required a "sufficiently fast" and correct response to earn a small positive addition to the total score (+1 point). A reaction was considered sufficiently fast only if it was faster than the median reaction time computed across the previous two trials. If no reaction time was available (as for the first two trials), or if a previous reaction had been slower than 1,000 msec, a value of 1,000 msec was used for the computation of the median. The participants were not informed about the exact algorithm used to determine an insufficiently fast response speed, but they knew that they had to react very quickly to avoid losses (which they were often unable to do). Reactions evaluated as too slow, incorrect, or both resulted in large deductions from the total score (−10 points if the reaction was either too slow or incorrect, −20 points if it was both too slow and incorrect), and an aversive auditory–visual feedback was displayed to make this heavy loss unavoidably obvious. Because slow and incorrect responses to this type of nonwords resulted in heavy losses and aversive feedback, these nonwords were referred to as negative.

Nonwords constructed with the vowel *e* did not require a fast response. Rather, correct responses resulted in a small gain (+1 point) and incorrect responses resulted in a small loss (−1 point) no matter how long the participants took to respond. These auditory nonwords were referred to as neutral. Nonwords constructed with the vowel o required no response at all; nothing was added to or subtracted from the participant's total score, and the next trial began automatically after a delay of 800 msec. These auditory nonwords were referred to as irrelevant. A second reason to include this condition (see the introduction for the first reason) was to prevent participants from adopting the strategy of responding as quickly as possible in any given trial, regardless of type (negative or neutral). Such a strategy might have prevented the participants from learning the association between vowel and type.

For each participant, the vowel (*a*, *e*, or *o*) that identified the stimuli as negative, neutral, or irrelevant was determined at random but then remained constant throughout the experiment. The valence induction phase consisted of 168 judgment trials, 56 of each type (negative, neutral, and irrelevant). The succession of trials was determined randomly for each participant.

The serial recall phase consisted of eight blocks, each of which was composed of 42 consonant judgment trials as in the first phase of the experiment (14 of each type: negative, neutral, and irrelevant), followed by eight serial recall trials. Seven of the negative and 7 of the neutral judgment trials of each block required the *l* response and the remaining half of each type of trials required the *z* response. Each auditory nonword (see the Materials section and the Appendix) occurred exactly once.

Each of the eight serial recall trials of each block consisted of a sequence of four visually presented target words that were randomly drawn without replacement from the seven three-syllable target words. Each word was visible for 600 msec, with no pause between words. For serial recall trials with auditory distractors, the onset and offset of each visual target occurred simultaneously with the onset and offset of one 600-msec auditory distractor. In addition, each series of four targets and distractors was followed by two additional distractors, which filled the 1,200-msec retention interval before the participants were to recall the targets. For the silent control condition, the temporal parameters were identical, but no distractors were presented with the targets or during the retention interval.

The eight sequences of target words of each block were presented thus: Two were presented in silence, followed by a 1,200-msec silent retention interval. Two were accompanied by a series of four different 600-msec irrelevant auditory nonwords, followed by two different 600-msec irrelevant auditory nonwords during the retention interval. Two were accompanied by a series of four different 600-msec neutral auditory nonwords, followed by two different 600-msec neutral auditory nonwords during the retention interval. Two were accompanied by a series of four different 600-msec negative auditory nonwords, followed by two different 600-msec negative auditory nonwords during the retention interval. Thus, the presentation of the four target words took 2,400 msec, and was followed by a 1,200-msec retention interval, which was silent or filled with irrelevant, neutral, or negative nonword distractors, depending on the distractor condition. After that, a question mark appeared on the screen, prompting the participants to recall verbally the target words in the order in which they had been presented. The participants' spoken recall was tape-recorded for later evaluation. The participants pressed a key on the computer keyboard to initiate the presentation of the next sequence of target words.

The succession of the eight sequences within each block was random. The eight blocks of the serial recall phase contained a total of 16 sequences of four items within each distractor type condition (silent, negative, neutral, and irrelevant). On average, the experiment lasted about 60 min, after which the participants were offered an explanation of the purpose of the experiment.

Design

The within-subjects independent variables were distractor type (silence vs. irrelevant auditory nonword distractors vs. neutral auditory nonword distractors vs. negative auditory nonword distractors) and serial position. The dependent variable was the number of visually presented target words that the participants recalled at the serial position at which they were presented.

Given a total sample size of $N = 46$, $\alpha = .05$, and the assumption that the average population correlation between the four levels of each repeated measures factor is $\rho = .7$, effects of size $f = 0.25$ (i.e., "medium" effects as defined by Cohen, 1977) could be detected for the global distractor type variable with a probability of $1 - \beta > .99$.[1] The power to detect effects of that size in binary comparisons of two levels of the distractor type variable was $1 - \beta = .95$.

RESULTS

Figure 1 shows that, in line with the experimental manipulation, responses were much faster for negative than for neutral nonword types [$t(45) = 8.33$, $p < .001$, $\eta^2 = .60$] and errors were much more frequent for negative than for neutral nonword types [$t(45) = 7.58$, $p < .001$, $\eta^2 = .56$].

Figure 2 illustrates the serial recall performance in all four distractor type conditions. The left panel of Figure 2 shows the absolute number of items recalled separately for each serial position (maximum of 16), and the right panel shows the average, in percent correct, across all serial positions. A 4 × 4 repeated measures MANOVA with distractor type and serial position as independent variables showed significant main effects of distractor type [$F(3,43) = 10.50$, $p < .01$, $\eta^2 = .42$] and of serial position [$F(3,43) = 82.08$, $p < .01$, $\eta^2 = .85$]. The interaction between both variables was not significant [$F(9,37) = 1.22$, $p = .32$, $\eta^2 = .23$].

We used orthogonal contrasts on the distractor type variable to test more specific hypotheses about the effects of the different distractor types. The first of these orthogonal contrasts showed that the difference between the silent control condition and all other conditions combined was significant [$F(1,45) = 25.21$, $p < .01$, $\eta^2 = .68$], confirming that there was a typical irrelevant speech effect. Second, the negative auditory nonword distractors

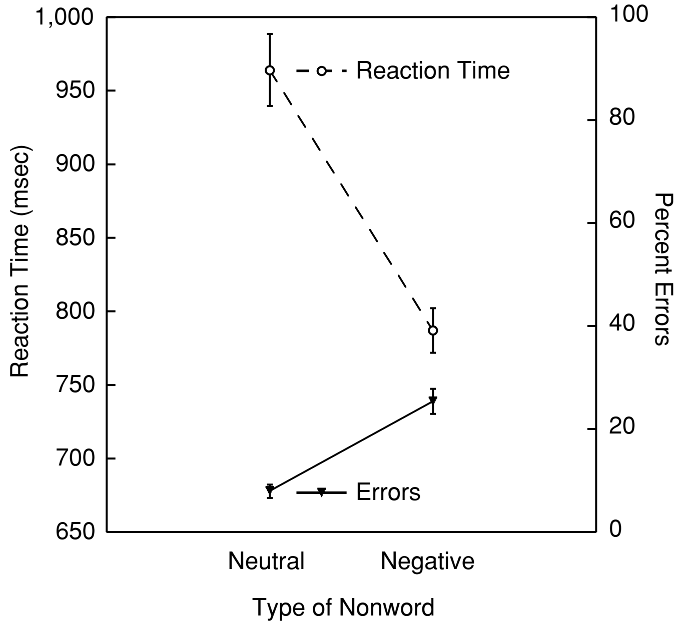

Figure 1. Reaction times and error percentages to neutral and negative nonwords during the induction phases. The error bars represent the standard errors of the means.

condition differed from the irrelevant and neutral conditions [$F(1,45) = 8.08$, $p < .01$, $\eta^2 = .15$], showing that the negatively valent nonword distractors caused more disruption in serial recall than did the irrelevant or neutral distractors. Third, the irrelevant and neutral distractors did not differ in their effect on serial recall performance [$F(1,45) = 0.36$, $p = .55$, $\eta^2 < .01$].

DISCUSSION

The present experiment conceptually replicated earlier results and confirmed earlier conclusions that distractor valence may affect serial recall (Buchner et al., 2004). Negatively valent auditory distractors impaired serial recall of visually presented words more than neutral or irrelevant distractors did. These results run parallel to research that, using the Stroop task, showed that negative-trait adjectives delayed the naming of the color in which they were printed more than neutral words did, which has been interpreted to suggest that valent-trait adjectives may automatically attract and consume attention at the expense of resources available to concurrent cognitive processes (McKenna & Sharma, 1995; Pratto & John, 1991; Williams et al., 1996; see also Algom et al., 2004; McKenna & Sharma, 2004). This is to be expected because valent-trait adjectives carry meaning in that they provide information about the state of the environment that requires attention. More generally, it has been shown in many other experimental paradigms that the processing of valent content automatically alerts the cognitive system to redirect processing resources to the behavioral demands that are signaled by the valent stimuli, interrupting ongoing cognitive processes (Klinger, 1996; Rothermund, Wentura, & Bak, 2001; Wentura & Rothermund, 2003; Wentura, Rothermund, & Bak, 2000). We suggest that this interruption also occurs in the processes involved in maintaining to-be-recalled information in working memory.

Note that the data of the present experiment cannot be explained by acoustic differences between distractors with differing valence characteristics (Banse & Scherer, 1996) because whether a particular distractor type (defined by the use of *a*, *e*, or *o* as vowel constituents) was presented as negative, neutral, or irrelevant was randomly determined. Moreover, by finding a significant contrast between negative and neutral distractors, we were able to exclude the possibility that simple stimulus–response associations, rather than the threat of a heavy loss and an aversive feedback, is the key variable that determines the disruption of serial recall by auditory distractors.

The valence effects on serial recall performance observed here can be readily accounted for by Cowan's (1999) conception of working memory, which proposes, in short, that rehearsed target elements represent the focus of attention; that is, they are the elements of memory kept at the highest activation levels. Negative distractors signal threats and thus attract attention automatically. This implies a diversion of processing resources away from the currently attended object representations, which reduces their activation levels and, consequently, the probability of their successful recall. The feature model (Nairne, 1990; Neath, 2000) can also account directly for effects of negative distractor valence on serial recall. Within this model, an attentional parameter reflects the amount of processing resources available for the primary memorization task.

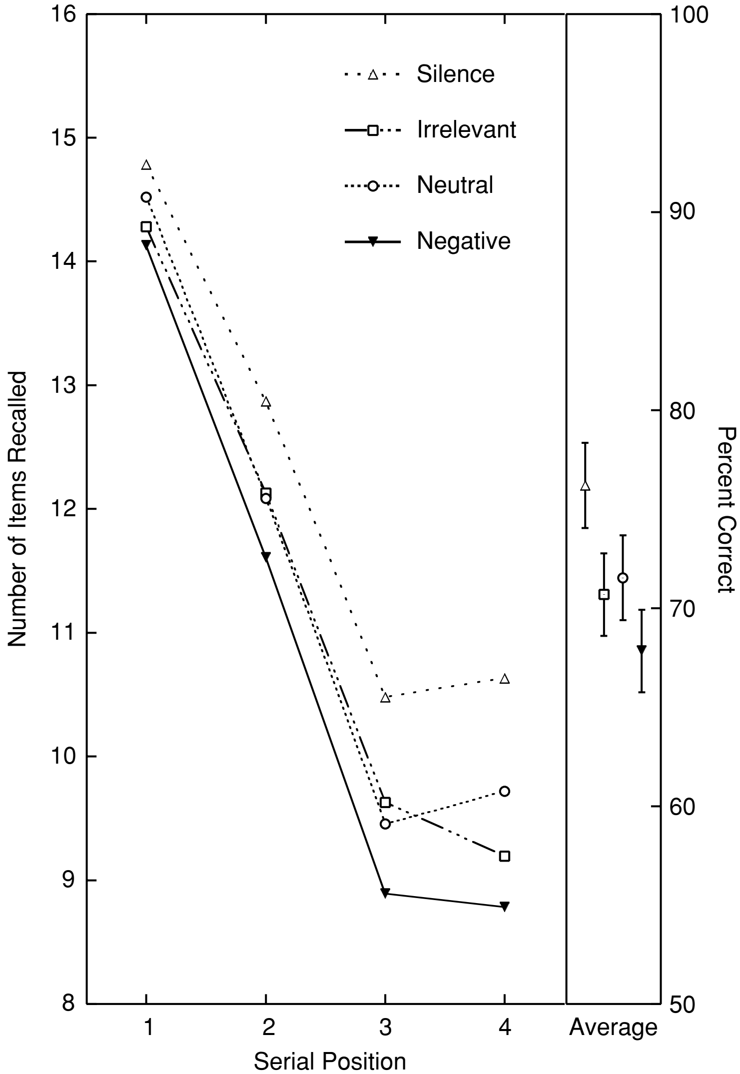

Figure 2. Cumulated number of words recalled correctly at each of the four serial positions (left panel and left *y*-axis) and percent correct averaged across serial positions (right panel and right *y*-axis) as a function of distractor condition. The error bars represent the standard errors of the means.

Assuming that orienting toward valent auditory distractors requires, on average, more attentional resources than orienting toward neutral or irrelevant distractors implies that the memorization task would be disrupted to a greater degree by valent than by neutral distractors.

Whereas these models provide a straightforward explanation of the valence effects reported here and elsewhere (Buchner et al., 2004), the status of these models is also determined by how well they can explain other irrelevant speech phenomena. For instance, an important finding is that a single repeatedly spoken distractor letter impairs performance less than a spoken random sequence of four letters does (Jones, Madden, & Miles, 1992). Within Cowan's (1999) conception of working memory, this could be explained by the fact that habituation to the repeated distractor occurs, in the process of which fewer and fewer attentional resources are directed toward it. Habituation does indeed seem to occur for noise as complex as background speech or office noise (Banbury & Berry, 1997). The feature model can explain this finding using a similar assumption (see Neath, 2000, for more detail). However, Jones and Tremblay (2000) have pointed out that some findings cannot be explained by the feature model, and it seems that many of these findings also cannot be explained within Cowan's conception of working memory. A prominent instance of this limitation concerns the role of perceptual organization, which is emphasized by the object-oriented episodic record model (Jones, 1993). For example, serial recall is disrupted if three different utterances are played repeatedly so that they appear to originate from one source in space, creating a within-stream changing-state situation. Disruption is reduced if each type of utterance appears to originate from its own distinct location (e.g., from the left, the middle, or the right) so that, for each source, the same utterance appears to be repeated over and over (Jones & Macken, 1995). This is similar to the single repeated distractor condition just mentioned. Both the feature model and Cowan's conception of working memory would have to be extended to include mechanisms of perceptual organization in order to explain findings such as this one (see Jones & Tremblay, 2000, for a more thorough discussion).

Note that Buchner et al. (2004) obtained an interaction between irrelevant sound and serial position because the decrement in the recall of the relatively long three-syllable target words caused by irrelevant auditory distractors was not uniform across serial positions, but instead was most pronounced at Serial Positions 4 and 5 and least pronounced at the final (sixth) serial position. This was originally interpreted as problematic for the feature model, which predicted a uniform performance decrement when irrelevant auditory distractors accompanied the task of memorizing visually presented target words relative to a silent control condition. With the shorter sequences of target words in the present experiment, no such interaction was obtained, and this pattern of data is compatible with the feature model. Given the present results, we think it likely that with relatively long lists of visual targets (defined in terms of the number of syllables comprised by the entire set of targets) participants resort to a strategy of neglecting intermediate serial positions when concurrent auditory distractors make memorization particularly difficult. This strategy shift is beyond the explanatory ambition of the feature model (and in fact, of any of the working memory models considered here), which is why we suggest that interactions of irrelevant sound and serial position with long lists of visual targets should not be used for model evaluation.

In contrast to Cowan's (1999) conception of working memory and the feature model, the object-oriented episodic record model (Jones, 1993) does not specify a role for attention in the maintenance of information for immediate serial recall. An analogous conclusion applies to the modular working memory model (Baddeley & Logie, 1999). According to this model, the task of maintaining lists of visually presented words for immediate recall is accomplished by converting the words into an articulatory representational format so that they can be maintained in the limited-capacity articulatory loop module of working memory. In contrast to the object-oriented episodic record model, the modular working memory model does specify attentional functions which are identified with the so-called central executive. However, "the central executive . . . is not involved in temporary storage" (Baddeley & Logie, 1999, p. 28), which is why attentional manipulations must not affect the maintenance of articulatorily recoded verbal information in the hypothetical phonological loop structure of working memory. Specifically, attentional distraction by valent distractors is a phenomenon that this model, in its current state of development, cannot predict, at least not as long as the strict separation between attentional functions and temporary storage functions is maintained. Interestingly, Meiser and Klauer (1999) suggested extending the modular working memory model by adding the auxiliary assumption that the central executive might contribute to performance in short-term retention tasks through the involvement of coordinative and supervisory functions. They showed that secondary tasks with high demands on central executive processes interfered more with serial recall performance than did tasks with lower central executive demands. Such an extension would imply the abandoning of the restriction that attentional and temporary storage functions were separate and could be assigned to distinct "modules." The extension would serve to make the modular working memory model compatible with the present data as well as with other data suggesting that attention is indeed involved in the maintenance of information in working memory (Buchner & Erdfelder, 2005; Buchner et al., 2004; Elliott, 2002). However, this would also imply abandoning one of the central characteristics of the model—that is, the modularity of working memory functions.

A similar modification could probably be applied to the object-oriented episodic record model (Jones, 1993). For instance, it could be assumed that the seriation of objects required attention and suffered not only from competing seriation processes within the representational structure used to temporarily maintain information, but also from attention distraction to behaviorally relevant events. Such an assumption seems possible but, to our knowledge, has not yet been suggested.

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NOTE

1. The power calculations were conducted using the G*Power program (Buchner, Faul, & Erdfelder, 1996; Erdfelder, Faul, & Buchner, 1996).

APPENDIX
Nonwords Used in the Present Experiment

Vowel Constituent		
a	*e*	*o*
Terminal Consonant *l*		
adabal	edebel	odobol
adaxal	edexel	odoxol
afamal	efemel	ofomol
afaral	eferel	oforol
arapal	erepel	oropol
aratal	eretel	orotol
awabal	ewebel	owobol
Terminal Consonant *z*		
adabaz	edebez	odoboz
adaxaz	edexez	odoxoz
afamaz	efemez	ofomoz
afaraz	eferez	oforoz
arapaz	erepez	oropoz
arataz	eretez	orotoz
awabaz	ewebez	owoboz

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