Phonological Information Contributes to Short-Term Recall of Auditorily Presented Sentences

Ralf Rummer and Johannes Engelkamp
Saarland University, Saarbruecken, Germany

Potter and Lombardi (1990) suggested that verbatim short-term recall of sentences solely depends on conceptual and lexical information. In two experiments, we show that phonological information also contributes to short-term sentence recall. Modality of sentence presentation was varied, and a word list was presented before or after sentence presentation. It was assumed that phonological information contributes to the recall of auditorily presented sentences but not to sentences presented under rapid serial visual presentation. Therefore, better recall was expected for auditory than for visual sentence presentation. However, the advantage of auditory presentation should only appear if the word list preceded the sentences and did not interfere with phonological sentence information. Thus, word-list position should influence recall after auditory but not after visual sentence presentation, as in the latter case the impact of phonological information should be greatly reduced. The predictions were clearly confirmed. In addition, we replicated Potter and Lombardi’s (1990) conceptually motivated intrusion effect.

Key Words: phonological storage; sentence processing; sentence recall; modality of presentation.

Performance in immediate (serial) recall of sentences is much better than performance in immediate serial recall of syntactically unrelated word lists. In syntactically related word lists (i.e., sentences), 12 or more words can be recalled verbatim (e.g., Butterworth, Shallice, & Watson, 1990). In contrast, memory performance for unrelated word lists is restricted to six or seven items (e.g., Baddeley, 1986).

Traditional explanations of this phenomenon concentrate on the role of surface encoding of sentences. Short-term sentence recall is regarded as involving a process of “reading off” the transient surface representations of a sentence—for example, the phonological information (cf. Glanzer, Dorfman, & Kaplan, 1981).

The central assumptions behind these explanations are (1) that verbatim sentence recall results from surface representations and not from conceptual information and (2) that surface representations decay if a conceptual representation of a clause is available (e.g., Caplan, 1973; Jarvella, 1971; Jarvella, Snodgrass, & Adler, 1978; for a critical overview cf. von Eckardt & Potter, 1985).

In contrast to these explanations, Potter and Lombardi (1990) claim in their conceptual regeneration hypothesis that short-term sentence recall differs from short-term list recall in that it is mainly based on conceptual representations. These conceptual representations are generated during the (auditory or visual) presentation of a sentence. Hence, surface information (e.g., phonological representations) does not contribute to short-term sentence recall. Applying the findings from lexical access in language production (e.g., Levelt, 1989) to reproduction of sentences, Potter and Lombardi (1990) assume that immediate sentence recall is verbatim because the lemma of a recently presented word (i.e., an abstract lexical representation of the word) is more highly activated than the lemma of a different word that shares the conceptual representation. Therefore, lexical access of pre-
viously presented words is more likely than lexical access of their synonyms. Thus, a “sentence is generated in immediate recall from a representation of its meaning using recently activated words” (Potter & Lombardi, 1990, p. 633).

Evidence for the conceptual regeneration hypothesis stems from a series of experiments that were conducted using the intrusion paradigm (see also Lee & Williams, 1997; Lombardi & Potter, 1992). The original intrusion paradigm was realized by using the following four-phase experimental trial structure: In the first phase of the trial, participants were presented with a sentence of 11 to 15 words. Depending on the experimental condition, this sentence was presented either visually or auditorily. For the visual presentation, the rapid serial visual presentation technique (RSVP; cf. Potter, 1984a; see also Forster, 1970) was used; for the auditory presentation, sentences were presented with normal intonation and rhythm, with the mean duration of the utterance matching the presentation time of RSVP. In the second phase of each trial, a list of five unrelated words was presented in the same modality as the sentence. For each list–sentence combination, two versions existed: Half the lists included a lure word which was approximately synonymous to one of the nouns in the sentence (i.e., the target word). In the other half of the lists, the lure word was replaced by a noun unrelated to the target word. This word is referred to as the control word, with the corresponding condition being the control condition. In the third phase of the trial, a probe word was presented, and subjects had to decide whether it was part of the preceding word list or not. For example, the sentence “The history professor waited impatiently for his reply to the unexpected question” was followed by the words “answer energy market island doctor” in the lure condition and “country energy market island doctor” in the control condition. In this case, the probe word, which was either a word that appeared in the list or one that did not, was NICKEL. In the fourth and final phase, participants were instructed to recall the sentence as accurately as possible.

Potter and Lombardi (1990) predicted that the lure word should replace the critical target word more frequently in recall if it was part of the list. Thus, intrusions should be more likely in the lure condition than in the control condition. That is what they observed. Moreover, if the lure was not in the word list (i.e., in the control condition), it was assumed to spontaneously intrude into sentence recall because lures were chosen in such a way that they appeared more appropriate in the sentence than target words (in the above example “answer” was considered to be more appropriate than “reply”). This spontaneous occurrence of lures in recall was also observed.

In contrast, a model that explains verbatim sentence recall in terms of excellent surface representations of sentences predicts no difference between the lure and control conditions. This should hold true because lure word and target word differ with respect to their phonological surface, and thus, the lure word will not be selected for the target word during sentence recall. However, Potter and Lombardi (1990) observed a higher probability of intrusions in the lure condition than in the control condition. Because lure and target words only resemble each other with regard to their conceptual representation, but are easily distinguished with regard to their phonological surface, they concluded that the contribution of phonological information to sentence recall can be, at best, very restricted.

Recently, though, the conceptual regeneration hypothesis was questioned by neuropsychological data presented by Martin (1993) and Martin, Shelton, and Yaffee (1994). E.A., a patient with a considerable impairment of her phonological short-term memory [memory span < 2 items; for a detailed description of E.A. cf. Martin (1990)], was shown to perform normally on the sentence–picture matching task, a task that requires the individual to match sentences with pictures that show the critical information contained in the sentence. At the same time, however, E.A.’s performance on verbatim immediate sentence recall was very poor. Although the recalled sentences were almost correct in content, they differed in their surface structure. Another of Martin’s patients, A.B., showed the reverse data pattern (cf. Martin et al., 1994): He demonstrated normal short-term sentence recall, but
whenever a task was included which required the comprehension of a sentence, his performance was impaired. This double dissociation suggests that, at least with respect to immediate recall of auditorily presented sentences, the availability of phonological representations seems to be a necessary condition for verbatim sentence recall but not for sentence comprehension. Martin et al. (1994, p. 99) conclude that “the only point of disagreement [with Potter & Lombardi] is whether the phonological memory involved in list repetition also plays any role in sentence repetition. On the basis of the neuropsychological data we argued that it does.”

In line with this claim, Engelkamp and Rummer (1999) presented experimental data that suggest that phonological short-term representations contribute to the immediate serial sentence recall of nonimpaired participants. In their experiments, participants were auditorily presented with two sentences which they had to recall immediately after the presentation of the last word. The sentences varied with regard to (1) the word length of the nouns in the sentences (monosyllabic versus three-syllabic nouns) and (2) their syntactic surface structure (two temporally or causally related events were expressed in subordinate versus coordinate sentences). Both manipulations were shown to independently influence recall performance. Only the word-length manipulation is relevant to the question of whether phonological information contributes to sentence recall. Engelkamp and Rummer (1999) showed that sentences with short nouns were recalled better than sentences with long nouns. Presuming that the word length effect indicates that the phonological subsystem of working memory—the phonological loop—is involved in memory performance (cf. Baddeley, Thomson, & Buchanan, 1975), this result can be interpreted as evidence for the contribution of phonological short-term representations to immediate serial recall of sentences.

Given findings like those reported by Martin et al. (1994) and Engelkamp and Rummer (1999), we believe that Potter and Lombardi (1990) go a step too far with their conceptual regeneration hypothesis. The data from Martin et al. (1994) and Engelkamp and Rummer (1999) suggest that they put too much weight on conceptual regeneration. We agree with Potter and Lombardi (1990) that conceptual information plays an important role in sentence processing (it is sentence meaning which we are habitually aiming at) and that this also holds true for short-term sentence recall. However, we assume that phonological information is also involved in short-term sentence recall, at least with auditorily presented sentences. Potter and Lombardi’s (1990) experiments aimed at demonstrating that conceptual information contributes to verbatim short-term sentence recall. Consequently, their experiments were not aimed at demonstrating that phonological information is also involved in sentence recall. In five out of seven experiments they presented the sentences visually (using RSVP), and in only two were the sentences presented auditorily. Unfortunately, in both auditory experiments, subjects were presented with a word list after listening to the sentence. In our view, this might have erased the phonological traces of the sentences and therefore no effect of phonological information was observed. Thus, Potter and Lombardi’s intrusion experiments do not allow for the conclusion that short-term sentence recall does not require acoustic and/or phonological information. Along with Lee and Williams (1997, p. 171), we believe that “the issue about the involvement of surface memory is still very much open.” It is therefore the main goal of this paper to demonstrate that phonological information is involved when sentence presentation is auditory (and when it is not interfered with by a following word-list presentation).

Before we develop our hypotheses with regard to the special conditions used in our experiments, it is necessary to make some remarks on the modality effect (e.g., Cowan, 1984, 1995; Frankish, 1995; Penney, 1989). This effect implies that recall (and also recognition) for auditorily presented verbal material is better than that for visually presented material. According to Penney (1989), the reason for the modality effect is a fundamental processing difference between auditory and visual items. Auditory items automatically generate an acoustic representation which is subsequently encoded phono-
logically. This phonological encoding process is automatic and thus appears very quickly and without any loss of information. Visually presented items generate a visual code. This visual sensory information is also processed phonologically. However, differently from auditory items, the phonological recoding of visual information needs a controlled and thus time-consuming recoding process.

According to this position, recall of auditory lists benefits from acoustic and phonological information, whereas recall of visually presented lists, due to the rapid decay of visual sensory information (Penney, 1989, p. 399), solely depends on phonological representations. Acoustic information should only be available for the last item positions of a list, so that the modality effect is larger for the three or four most recent words than for the preceding items. This latter effect was also shown for sentences (Balota, Cowan, & Engle, 1990).

We suggest modifying this position and distinguishing between the automatic and the strategic use of phonological information with visual material. There is a good deal of research which suggests that visual words also access meaning through a phonological code (e.g., Lukatela & Turvey, 1994a, 1994b; van Orden & Goldinger, 1994) and that this phonological recoding is extremely rapid and unconscious. We assume that this kind of phonological information mainly serves to transport the meaning of words, and that it decays rapidly and does not itself support immediate recall. In addition, we assume that there is a controlled phonological recoding (cf. Penney, 1989) which corresponds with putting the phonological information into a phonological short-term store (STS) (e.g., Baddeley, 1986). This kind of phonological recoding is critical for short-term serial recall. It is this input in the phonological STS that occurs automatically with auditory presentation. Moreover, short-term recall of auditorily presented material is supported by acoustic information which decays more slowly than visual information. A similar proposal was made by Besner and Davelaar (1982). They suggested distinguishing two levels of phonological processing: First, phonological forms of the words are activated, and second, phonological information enters the phonological STS. Only phonological information which has entered STS can be actively retained.

Strategic recoding of visual information into the phonological STS is particularly relevant for the comparison between RSVP and auditory presentation. We assume that auditorily presented materials are automatically entered into the phonological STS (and can thus be actively retained in it), whereas RSVP, because of the rapid presentation rate, prevents materials from entering phonological STS (but see Coltheart, 1999). More precisely, participants should refrain from phonological recoding if the presentation rate is faster than the time-consuming recoding process. Evidence for the assumption that phonological information does not enter STS under RSVP stems from Potter (1984b; cited in Potter, 1999). She found that concurrent articulation during RSVP reading did not affect short-term sentence recall (cf. also Potter, 1993).

An important point is that the advantage for auditorily presented sentences should disappear if sentences are followed by subsequent verbal stimuli. This influence is obvious in the suffix effect (Crowder, 1967; Dallet, 1965). The question of whether this interference effect is due to acoustic or phonological information is still awaiting a definite answer (e.g., de Gelder & Vroomen, 1997; Greene, 1992, Chap. 2). Since we only used verbal material, we do not focus on this distinction. In our experiments both effects should merge. For the sake of simplicity, we will generally use the term phonological information in this article. Regardless of whether the effects are more auditorily or phonologically based, if they occur in our experiments they still argue against a purely conceptual basis of sentence recall.

To sum up, for the recall of sentences presented under RSVP and auditory presentation we expect two effects. First, we expect a recall advantage for the auditory presentation over RSVP due to acoustic and phonological representations. Second, we expect a phonological interference effect only under auditory sentence presentation. This effect should be particularly obvious for the last positions of a sentence.
In order to test these assumptions, we varied two factors orthogonally. The first factor concerns the sequence of sentence and list presentation. The second factor concerns the modality in which the sentences and word lists were presented (RSVP and normal auditory presentation). An orthogonal variation of these two factors results in four experimental conditions: (1) RSVP with the word list following the sentence (vis SL); (2) RSVP with the word list preceding the sentence (vis LS); (3) auditory presentation with the word list following the sentence (aud SL); and (4) auditory presentation with the word list preceding the sentence (aud LS). Potter and Lombardi (1990) only realized the first three conditions. However, the forth condition is needed to test the assumptions concerning the phonological code.

If sentences are presented under RSVP and auditorily without list interference (aud LS), there should be a recall advantage (proportion of correctly reproduced words) for the auditory presentation over RSVP (vis LS and vis SL) because under auditory presentation, sentence recall should benefit from the phonological code. As outlined above, the subsequent presentation of a word list should only erase the phonological code. Since we assume that phonological information is only available in the auditory modality, the list–sentence sequence should only be critical for auditorily presented material. Therefore, sentence recall should be worse under auditory presentation when the word list follows (aud SL) than when it precedes sentence presentation (aud LS). However, this variation of list position should hardly affect RSVP because here sentence recall is based on conceptual information which is unlikely to be influenced by list position. Hence, we expect an interaction between the factors of sequential order and modality.

This global pattern of sentence recall should be modified if the positions of the words in the sentences are taken into account. As mentioned above, the phonological trace should be particularly available for the last three or four positions of a sentence. Therefore, an interaction of sequential order and item position should only be observed for the auditory but not for the visual modality. The last three items should particularly suffer from a list following an auditory sentence. In contrast, with RSVP, phonological traces are not available for the first or for the last three words of the sentences. Thus, the influence of the sequential order of list and sentence should not differ with respect to the item position under RSVP.

With respect to lure intrusions we have the following expectations: First, with Potter and Lombardi (1990) we generally expect more intrusions if a lure word was presented within the list as compared to the case when the lure word was not presented. This effect, which is due to conceptual information, is expected for all experimental groups. Second, we do not expect differences in intrusions depending on the sequential order of list and sentence under RSVP because here only conceptual information is decisive. Third, for auditory presentation we expect fewer intrusions if the lists precede the sentences than if they follow them. This should hold true because under the former condition the phonological code should enhance the phonological discrimination. Fourth, in the case that auditory sentences are preceded by word lists, the number of intrusions should also be reduced compared to RSVP for the same reason.

**EXPERIMENT 1**

The first experiment constitutes a replication of Experiments 1, 2, and 6 by Potter and Lombardi (1990) with the additional inclusion of an experimental condition with auditory presentation and the lists preceding the sentences (aud LS). The experiment is based on a three-factor design with the first two factors, modality of presentation (RSVP vs auditory presentation) and sequential order of sentence and list presentation (list before sentence vs. list after sentence), serving as between-subjects variables and the third factor, lure condition (list with or without lure word), serving as a within-subjects variable. Half the lists included the lure word. In the other half, the lure word was replaced by a semantically unrelated word. In order to make feasible an overall analysis of the experimental design, we modified the original experimental
procedure used by Potter and Lombardi (1990). In the present experiment, all experimental groups were presented with the same material, whereas the sentences and word lists in Potter and Lombardi’s (1990) Experiment 6 (and SL) differed from the material presented in Experiments 1 (vis SL) and 2 (vis LS).

Method

Participants. Sixty-four students from Saarland University, all of them native speakers of German, participated in the experiment. They were paid for their participation. Sixteen people were randomly assigned to each of the four experimental conditions.

Material. The 20 sentences presented in Experiments 1 and 2 by Potter and Lombardi (1990) were translated into German. Each sentence included a target word. Importantly, as in the original English sentences, the target words always appeared in the middle of the sentences. Two lists were constructed, each including five unrelated words for each sentence. In the lure condition, a word that was semantically similar to the target word was presented in the word list. As in the original study, lure words were chosen such that they appeared more suitable in the context of the sentence than the target word itself. In the control condition, a noun that was neither semantically nor phonologically related to the target word replaced the lure word. Except for the lure word/control word, the two word lists were identical. The materials are given in the Appendix.

In the two visual presentation conditions, sentences, word lists, and probe words were presented on the computer screen; in the two auditory presentation conditions, sentences, word lists, and probe words were presented by means of external loudspeakers. In the auditory condition, sentences, word lists, and probe words were read aloud and with natural prosody by a male speaker. The reading was digitized and stored on a personal computer.

Procedure. In all experimental groups, half the sentences were presented in combination with lists that included a lure word and the other half were presented together with lists that did not include a lure word. The assignment of the lists to one of these conditions was determined at random, as was the presentation order of the 20 sentence–list combinations.

Visual presentation. The two visual presentation groups replicated Potter and Lombardi’s Experiments 1 and 2. Word lists and sentences were presented in the center of the screen using the RSVP technique.

The structure of a single trial in the list before sentence condition was as follows: Participants started a trial by pressing the space bar of the computer keyboard. Three asterisks then appeared for 300 ms at the center of the screen, followed by a blank screen for 350 ms. Following this, the words of the word list were presented one after the other for 250 ms per word. The sentence was presented after an interval of 250 ms in which a row of percentage signs was displayed. Each word of the sentence was displayed separately on the screen with a presentation rate of 200 ms per word (stationary window). As soon as the last word of the sentence had vanished from the screen, the row of percentage signs appeared for 517 ms. Finally, the probe word was presented in capital letters for 500 ms. Subjects had to decide whether the probe word had been part of the word list or not, and then respond by pressing one of two response keys (shift-right for “yes,” shift-left for “no”). Participants were told that this matching task served to increase the difficulty of the sentence recall which had to be done immediately afterward. For the sentence recall, participants were instructed to recall the sentence aloud and as accurately as possible.

The list after sentence condition only differed with respect to the order of list and sentence presentation. As in the list before sentence condition, the subjects first responded to the probe word and then recalled the sentence aloud.

Auditory presentation. In comparison with the two visual presentation conditions, the procedure in the two auditory presentation groups differed only with respect to the modality of the sentences and word lists. The timing of the sentence and the list presentation as well as the intervals between the sentence, the list, and the probe word matched as closely as possible those of the visual presentation groups. That is, on the
average, presentation time was 200 ms per word. Actually, content words of three syllables or more needed a bit more time, and one-syllable function words needed a bit less. All other aspects of the trial structure (i.e., the presentation of the asterisks and percentage signs) were equal to the visual conditions.

The sentences recalled aloud were recorded and transcribed. As dependent variables, the percentage of correctly reproduced words per sentence (excluding the target word) and the percentage of lure intrusions for the target word were measured.

**Results**

**Proportion of correctly reproduced words.**

Table 1 shows the mean percentage of correct recall as a function of the two independent variables, modality and order, for our experiments and those of Potter and Lombardi (1990). As can be seen in this table, the findings for the visual presentation mode (RSVP) show close correspondence between the two studies. However, the level of sentence recall in our experiment was generally lower than that in Potter and Lombardi’s experiments (1990). An explanation for this decrease may be found in the different properties of English and German. Measured in terms of the number of syllables, the mean length of the German sentences was higher than the mean length of the original English sentences (for English, $M_{vis} = 16.95$ and $M_{aud} = 17.2$ syllables per sentence, compared to German, $M_{vis} = 22.85$ syllables per sentence). A difference in recall between Potter and Lombardi’s experiments and ours was observed for auditory presentation with the list following the sentence (91% vs 65%). We will come back to this finding in the General Discussion.

We will now focus on the results of the present experiment. As Table 1 shows, under RSVP, recall was equally good for the SL and the LS conditions, whereas auditory recall for LS was better than that for SL. The different recall patterns for visual and auditory presentation resulted in a significant two-way interaction between modality and order ($F_1(1,60) = 10.65$, $MSE = 115.62$, $p < .01$; $F_2(1,19) = 27.42$, $MSE = 47.98$, $p < .001$) that modified a significant overall main effect of order ($F_1(1,60) = 14.53$, $MSE = 115.62$, $p < .001$; $F_2(1,19) = 33.72$, $MSE = 62.06$, $p < .001$). Planned comparisons (LSD tests) indicated that there was no difference between SL (75%) and LS (76%) after RSVP ($p_1$ and $p_2 > .1$). However, after auditory presentation, recall was better with LS order (84%) than with SL order (65%) ($p_1 < .001$ and $p_2 < .001$). Further comparisons revealed that, with SL, the visual presentation led to better recall than the auditory presentation (75% vs 65%; $p_1 < .05$ and $p_2 < .001$), and with LS, the opposite effect was observed; that is, recall was better with auditory than with visual presentation (84% vs 76%; $p_1 < .05$ and $p_2 < .001$).

In order to test the specific expectation that the phonological effect in the auditory LS condition should be confined to the end of the sentence, we carried out a further analysis of the recall performance on the first three and the last three words of each sentence. The results are summarized in Table 2. As expected, under RSVP there was no difference between recall performance for LS and SL, neither for the first three (91% vs 87%) nor for the last three words of the sentences (63% vs 62%). In contrast, under auditory presentation for both the first three and the last three words a difference between LS and SL was found. However, the difference was larger for the last three (75% vs 51%) than for the first three words (92% vs 78%).

**TABLE 1**

Mean Percentage of Correctly Reproduced Words as a Function of the Modality of Presentation and the Sequential Order of List and Sentence in Potter and Lombardi’s (1990) Experiments and in our Experiments 1 and 2

<table>
<thead>
<tr>
<th>Recall</th>
<th>Recall auditory presentation</th>
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<tr>
<td>RSVP</td>
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<td>Potter and Lombardi</td>
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<tr>
<td>LS</td>
<td>86</td>
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<tr>
<td>SL</td>
<td>89</td>
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<tr>
<td>Experiment 1</td>
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<tr>
<td>LS</td>
<td>76</td>
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<tr>
<td>SL</td>
<td>84</td>
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<td>75</td>
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<tr>
<td>SL</td>
<td>81</td>
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<td>88</td>
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</table>

*Note.* RSVP, Rapid Serial Visual Presentation; LS, List before Sentence; SL, List after Sentence.
We expected a three-way interaction between the factors modality, sequential order, and position of the words in the sentences. Indeed, the ANOVAs confirmed this prediction, $F_1(1,60) = 5.26; MSE = 59.47; p < .05; F_2(1,19) = 6.03; MSE = 64.82; p < .05$. In order to localize this interaction, we carried out separate ANOVAs for auditory and visual presentation with the factors of word position (first three vs last three words) and sequential order (LS vs SL). For auditory presentation, the two-way analysis revealed a significant main effect of the sequential order ($F_1(1,30) = 37.87, MSE = 147.73, p < .001; F_2(1,19) = 39.13, MSE = 178.69, p < .001$) that was qualified by a significant two-way interaction ($F_1(1,30) = 9.64, MSE = 44.14, p < .01; F_2(1,19) = 9.32, MSE = 57.04, p < .01$). A decrease, caused by the following word list, was greater for the last three than for the first three words of the sentences. However, the effect of sequential order was significant for both the last three and the first three words in the sentences ($p_1$ and $p_2 < .001$). The ANOVA with RSVP showed neither a main effect for sequential order ($F_1 < 1; F_2(1,19) = 1.36, MSE = 95.54, p > .1$) nor an interaction (all $F$s < 1).

Our findings suggest that phonological information from the last words was particularly good if presentation was auditory and no interference took place, and it was particularly bad if presentation was auditory and interference by a following word list took place. For the first three words, this effect was significantly weaker.

Lure intrusions. Table 3 shows the proportion of lure intrusions as a function of the three independent variables of modality, order, and lure condition. The table shows that whenever a lure word occurred in the lists, more intrusions appeared than when the lure word was replaced by a conceptually unrelated control word. This lure intrusion effect was observed for all experimental groups. For lists that contained a lure word, a mean percentage of 18% lure intrusions was found, whereas for the control condition only 9% intrusions appeared. In addition, there were more intrusions in the auditory SL (24%)
than in the visual conditions (10% and 9%). Moreover, more intrusions were observed in the auditory SL condition (24%) than in the auditory LS condition (10%). Again, our findings seem to replicate Potter and Lombardi’s (1990) data quite well. That the number of intrusions is generally higher in Potter and Lombardi’s study than in ours may be due to syllabic differences between the English originals and the German translations.

An analysis of variance including the factors of modality, order, and lure confirmed these observations for our data. The ANOVA revealed a marginal three-way interaction: $F(1,60) = 5.23, \text{MSE} = 0.72, p < .05$; $F(1,19) = 3.66, \text{MSE} = 0.83, p < .08$. In order to localize this interaction, separate ANOVAs for the auditory and the visual condition were conducted. For the visual condition, there were no differences in the number of intrusions depending on order. The ANOVA revealed only a main effect of lure condition: $F(1,30) = 7.08, \text{MSE} = 0.56, p < .05$; $F(1,19) = 7.33, \text{MSE} = 0.44, p < .05$. Neither the main effect of order nor the interaction between order and lure was significant (all $Fs < 1$). As expected, the situation was different with auditory presentation. Here, the number of intrusions was higher when the lists followed the sentences (SL) than when they preceded the sentences (LS). The separate ANOVA for the auditory presentation groups revealed two significant main effects sequential order: $F(1,30) = 20.77, \text{MSE} = 1.456; p < .001$; $F(1,19) = 16.25; \text{MSE} = 1.489; p < .001$; lure condition: $F(1,30) = 31.28; \text{MSE} = 0.881; p < .001$; $F(1,19) = 14.23; \text{MSE} = 1.550; p < .01$ and a significant interaction between the two factors ($F(1,30) = 10.21; \text{MSE} = 0.881; p < .01$; $F(1,19) = 12.11; \text{MSE} = 0.595; p < .01$). If the word lists followed the sentences, the lure intrusion effect was higher than if the sentences followed the word lists.

However, as was shown by separate ANOVAs for visual and auditory presentations, differences in the number of intrusions appeared only if the lists followed the sentences. A separate ANOVA for the list after sentence condition revealed a significant two-way interaction for modality and lure, $F(1,30) = 12.03, \text{MSE} = 0.748, p < .01$; $F(2,1,19) = 7.28, \text{MSE} = 0.989, p < .05$; whereas, different from our assumptions, intrusions for auditorily and visually presented sentences did not differ if the sentences followed the word lists (all $Fs < 1$).

Discussion

The present experiment showed that recall of sentences presented with RSVP is mainly based on conceptual information. For this reason, there was no sequential order effect with RSVP. In this regard our data replicate the findings of Potter and Lombardi (1990).

The situation is different if the sentences are presented auditorily. Auditorily presented sentences were recalled better than visually presented sentences when the phonological code was not interfered with by a following acoustic word list. However, we cannot exclude that the slower presentation of long content words also facilitated conceptual encoding under this condition. Such a facilitating effect of conceptual information cannot explain the interaction between modality and list position though. For auditorily presented sentences followed by an (auditory) word list, on the other hand, recall was impaired compared to the list–sentence condition. In addition, sentence recall for the sentence–list condition was worse under auditory sentence presentation than under visual presentation. This effect was unexpected and different from the results of Potter and Lombardi (1990). We will postpone discussion of this effect until after we describe Experiment 2.

In a more detailed analysis, which took into account the position of the words in the sentences, we observed a three-way interaction among sequential order, modality, and position of the words in the sentences. This finding supports the assumption that recall of both auditory sentences and unrelated word lists uses phonological information. Obviously this information is used in auditory sentence recall. This is particularly true for the last three words if the list precedes the sentence, and it is impaired if a list follows the sentence. Hence, there is support for the hypothesis that sentence recall for auditorily presented sentences depends on phonological information and that this mainly holds true for
the last words of the sentences. This finding of modality-specific differences in sentence recall requires an extension of Potter and Lombardi’s (1990) account.

Potter and Lombardi’s (1990) basic regeneration hypothesis was also supported by the intrusion data in our experiment. However, there are two more specific findings that are worth mentioning. First, the number of intrusions was highest when sentences were auditorily presented and followed by a word list. Under this condition, the number of intrusions was higher than under RSVP, and it was higher than under auditory presentation if sentences followed the word lists. This was also found in the study by Potter and Lombardi (1990).

Second, contrary to our expectations, we did not observe fewer intrusions under auditory than under visual presentation when the lists preceded the sentences. A possible explanation for the absence of the expected modality effect is that the target words of the sentences were always located in the center of the sentences. That is, they were not located in the region of the sentence where phonological information is particularly available during sentence recall. A detailed discussion of these findings will be postponed until after we describe Experiment 2.

EXPERIMENT 2

In Experiment 1, we demonstrated that the advantage of auditory over visual sentence presentation is mainly due to the most recent items of a sentence. Because the target words were not located at the end of the sentences, but in the center, it seems likely that intrusions did not differ under LS as a function of modality. In this second experiment, we tested the assumption that the expected decrease in intrusions in the auditory LS condition will occur if the targets for the lure words are located at the end of the sentences. Here, the sentences are constructed so that the target is basically one of the three most recent words.

Method

Experiment 2 was based on the same three-factor design as Experiment 1. Two factors, modality of presentation (RSVP vs auditory presentation) and sequential order of sentence and list presentation (SL vs LS), served as between-subjects variables, and lure condition (list with or without lure word) served as a within-subjects variable. In comparison with Experiment 1, there was only one important difference: the target word in the present experiment occurred at the end of the sentences.

Participants. Sixty-four students from Saarland University, all of them native speakers of German, participated. As in Experiment 1, they were paid for participation. Sixteen individuals were randomly assigned to each of the four experimental conditions.

Materials. The only difference between Experiment 1 and Experiment 2 concerned the construction of the sentences. The 20 new items were constructed so that the target word was one of the three most recent words of the sentence. The materials are given in the Appendix.

As in Experiment 1, for each sentence, two lists including five unrelated words were constructed. In the lure condition, a word that was conceptually similar to the target word was presented in the word list. In the control condition, a noun that was neither conceptually nor phonologically related to the target word was presented instead of the lure word.

As in Experiment 1, sentences and word lists were presented on a computer screen in the RSVP conditions. In the auditory conditions, sentences and word lists were presented by means of external loudspeakers.

Procedure. Experimental procedures were exactly the same as in Experiment 1.

Results

As in Experiment 1, results are reported separately for the proportion of correctly reproduced words (excluding the target words) and the lure intrusions.

Proportion of correctly reproduced words. Table 1 shows the results for the proportion of correct recall as a function of the two independent variables of modality and order of presentation.

Recall of sentences presented with RSVP was equally good for the LS and the SL conditions (81% vs 82%), whereas in the auditory conditions, recall for LS was much better than for SL.
(88% vs 79%). These different recall patterns for visual and auditory presentation were reflected in a significant interaction between modality and order: $F(1,160) = 4.70, \text{MSE} = 67.49, p < .05$; $F(2,19) = 19.96, \text{MSE} = 17.8, p < .001$. In addition, there was a marginal main effect of order ($F(1,160) = 3.77, \text{MSE} = 64.49, p < .06$; $F(2,19) = 9.07, \text{MSE} = 33.53, p < .01$) that was modified by this interaction. Planned comparisons confirmed that there was no difference between SL and LS after RSVP (at comparisons confirmed that there was no difference between SL and LS after RSVP ($p > .05$) but after auditory presentation, recall was better for the LS than for the SL group ($p < .01$ and $p > .05$). For the LS condition, recall was better with auditory presentation than with RSVP (88% vs 81%; $p < .05$ and $p < .001$). Thus, the modality effect was replicated.

In contrast to the first experiment, however, recall with SL under RSVP was not significantly better than under auditory presentation (82% vs 79%; $p < .01$ and $p < .001$). For the LS condition, recall was better with auditory presentation than with RSVP (88% vs 81%; $p < .05$ and $p < .001$). Thus, the modality effect was replicated.

In order to test whether the most recent words of the auditory sentences were, again, most sensitive for the sequence effect, we scored recall performance separately for the first and last three words of each sentence. The results are summarized in Table 2. The ANOVA revealed a marginal three-way interaction among the modality of presentation, the sequential order of list and sentence, and the position of the words in the sentence, $F(1,160) = 3.07, \text{MSE} = 40.82, p < .09$; $F(2,19) = 3.18, \text{MSE} = 53.20, p < .1$. Again, we carried out separate ANOVAs for the auditory and visual conditions. The ANOVA for the auditory condition yielded a significant main effect of sequential order ($F(1,130) = 13.59, \text{MSE} = 117.75, p < .001$; $F(2,19) = 27.95, \text{MSE} = 72.45, p < .001$) which was qualified by a close to significant two-way interaction, $F(1,30) = 4.79, \text{MSE} = 46.94, p < .05$; $F(2,19) = 3.82, \text{MSE} = 79.82, p < .07$. As in Experiment 1, the sequential order effect was stronger for the last three words as compared to the first three words of the sentences. With RSVP, no main effect or interaction was found (all $Fs < 1$). Here, sequential order of lists and sentences had no effect on recall performance, neither for the first nor for the last words in the sentences.

**Lure intrusions.** Table 3 shows the proportion of lure intrusions as a function of the grouping factors modality of presentation and sequential order of list and sentence and of the within-group factor lure condition. If the lists preceded the sentences under RSVP, the lure replaced the target word in 30% of the recalled sentences, given that the lure was included in the word list. Even if the lure was not in the list, there were still 20% spontaneous intrusions. For the corresponding auditory LS group, the intrusions were 19% and 12%, respectively. When the lists followed the sentences under RSVP, 31% and 23% intrusions occurred, whereas for the auditory SL group the intrusions were 42% and 20%, respectively.

The ANOVA indicated a marginal three-way interaction: Whereas the $F(1,60) = 2.76, \text{MSE} = 1.916, p < .11$, the $F(2,19) = 1.91$, the $F(2,19) = 6.44, \text{MSE} = 2.35, p < .05$; $F(2,19) = 8.45, \text{MSE} = 1.50, p < .01)$. Whereas the proportion of intrusions within the auditory group depended on the sequential order of sentence and list (LS 16%, SL 31%), in the RSVP group the proportion of intrusions was independent of the sequential order (LS 25%, SL 27%). Planned comparisons (LSD test) showed that this interaction was particularly due to the auditory LS condition. As predicted, intrusions emerged less frequently in the auditory LS than in the other three conditions.

Experiment 2 particularly aimed at testing the assumption that the modality effect (i.e., the advantage of auditory over visual presentation in the LS condition) should also emerge for intrusions. For lists preceding the sentences, we predicted that the proportion of lure intrusions would be lower in the auditory than in the RSVP condition because phonological information is assumed to be available only under auditory presentation, and because the discrimination of lure and target word should benefit from phonological information. In order to test this hypothesis, a separate ANOVA for the two
LS groups with the between-subjects factor modality of presentation and the within-subjects factor lure condition was conducted. As expected, the ANOVA revealed a significant main effect of the modality ($F(1,30) = 5.71, MSE = 2.462, p < .05$; $F(2,19) = 10.26, MSE = 1.17, p < .01$): Intrusions appeared more frequently if sentence and word list were presented using the RSVP technique than if they were presented auditorily.

A separate ANOVA for the SL condition also confirmed our assumptions: The ANOVA revealed a significant main effect for lure condition ($F(1,30) = 13.26, MSE = 2.715, p < .01$; $F(2,19) = 18.12, MSE = 1.589, p < .001$) and a marginal two-way interaction between modality and lure condition, $F(1,30) = 2.79, MSE = 2.715, p < .11$; $F(2,19) = 8.24, MSE = 0.734, p < .01$). There were more intrusions with lures under auditory sentence presentation (42%) than under RSVP (31%; $p_1 < .07, p_2 < .01$).

**Discussion**

There was an almost perfect replication of the sentence recall pattern of Experiment 1. Sequential order had no effect with RSVP but had a clear effect with auditory presentation. Recall of auditory sentences was better if the list preceded the sentence than if it followed the sentence. In the former case (LS), phonological information was not disturbed and gave the auditory presentation an advantage over RSVP where the conceptual information was not (additionally) supported by phonological information. The only difference in sentence recall between the two experiments was that the interference effect with auditory presentation under SL was stronger in Experiment 1, so that a significant modality effect was observed only in the first. Potter and Lombardi (1990) did not find any difference between recall performance of auditorily (their Experiment 6) and visually (their Experiment 1) presented sentences in the SL condition. If conceptual information were independent of presentation modality, recall performance should be equal under the two presentation modalities. We do not have an explanation as to why this was not observed in Experiment 1. It should, however, be remembered that different sentences and lists were used in Experiments 1 and 2. For the auditory SL condition, the accidental phonological relationship between the list words and the sentence words should be critical for the degree of sentence recall. It is possible that this relationship was different in the two experiments. Moreover, the scores for the four recall conditions stem from four different groups of individuals. It might be that the participants in the auditory SL group of Experiment 1 were accidentally poorer in memory than those of the other groups, and/or those of Experiment 2 were relatively better. However, this unexpected finding does not weaken our predicted effects and conclusions drawn from them. The decisive point is that performance in auditory sentence recall is lower when the word list follows the sentence than when it precedes it.

The more specific prediction that the largest part of the modality occurs in the most recent part of the sentences was also confirmed. As expected, the word position by order interaction in both experiments was observed under auditory presentation but not under RSVP.

As expected, the pattern of intrusions differed between Experiment 1 and 2. Under RSVP, intrusions did not differ as a function of the sequential order of list and modality. This null effect was consistently found in our experiments and in the experiments performed by Potter and Lombardi (1990). However, the intrusion data of our experiments differed with respect to auditory sentence presentation. If the lists preceded the sentences, there were fewer intrusions with auditory than with visual presentation in Experiment 2, but not in Experiment 1. This difference was expected and ascribed to the fact that the positions of the targets for the lure words varied across the two experiments: In Experiment 1, the target words were located in the center of the sentences, whereas in Experiment 2 they were one of the three most recent words. The center positions do not differ with respect to the modality; the end positions do. As already demonstrated by the recall data, phonological information is mainly available for the most recent part of the sentences. Since the discrimination of lure and target words substantially benefits from this
phonological information, a modality effect in the LS condition only appears if a phonological representation of the target word is available during sentence recall. This is the case in Experiment 2 but not in Experiment 1.

The reverse effect was observed if the word list followed the sentence. Under this condition, the number of intrusions was higher under auditory presentation than under RSVP. This effect was observed in Experiment 1 and in the study of Potter and Lombardi (1990) as well. We do not have a straightforward explanation of this finding, which was not really explained by Potter and Lombardi either. A possible explanation might be that auditory presentation of the word list leads to an enhanced priming effect compared to RSVP which could reinforce the lure selection by the wrong phonological information of the lure under the SL condition. Admittedly, the issue of whether phonological activation feeds back to the lemma level to bias lexical selection in production is contentious (see Levelt, Roelofs, & Meyer, 1999, for discussion), but at least in the interactive activation model it seems possible that the phonological trace from the lure in the word list increases the probability that the corresponding lemma will be selected during the sentence recall process.

GENERAL DISCUSSION

Our experiments show that both conceptual and phonological information contribute to short-term sentence recall. The finding that a lure intrusion effect appeared in all experimental conditions demonstrates that sentence recall is based on conceptual information independently of the modality of presentation. This effect should only occur if sentences are regenerated on the basis of conceptual information. Thus, our data confirm the assumption that conceptual regeneration is the main basis of sentence recall.

The main goal of our experiments was to demonstrate that—besides conceptual information—phonological information also contributes to short-term recall of auditorily presented sentences. From our data, we can clearly conclude that this is indeed the case. If no word list is processed after sentence presentation, a clear modality effect occurs. That is, recall of auditorily presented sentences is better than recall of visually presented sentences. If the modality effect is due to the contribution of phonological information, the modality effect should disappear if a word list is processed after the presentation of the sentence. These assumptions were also confirmed by our data. The contribution of phonological information is conclusively reflected in the finding that its effect is particularly pronounced at the end positions of the sentences.

The restriction to the end positions tells us two things. First, the phonological contribution is limited and is presumably to be attributed to the content of a phonological short-term store (e.g., Potter & Lombardi, 1998) or to the contribution of an auditory sensory code (e.g., Balota et al., 1990). Second, it underlines Potter and Lombardi’s (1990) position that the generation process is the more important influence on short-term sentence recall.

We argued that phonological information is not represented in STS if sentences are presented under RSVP. Phonological recoding of the visual input information is considerably affected by the high presentation rate. Thus, with respect to the contribution of phonological information, RSVP is a special case which does not reflect the processes that generally appear in the short-term recall of sentences even under visual presentation. If the objective of an experiment is to demonstrate that verbatim recall of sentences is possible without using surface information (this was Potter & Lombardi’s objective), then the experimental procedure of RSVP is reasonable. However, if the objective is to demonstrate that, besides conceptual information, surface information also contributes to sentence recall, then RSVP is a rather inappropriate experimental procedure.

We reported at the beginning of our paper that E.A., who was subject to several investigations published by Randi Martin and co-workers, showed deficits in verbatim recall of auditorily presented sentences compared to the participants of an unimpaired control group (Martin, 1993; 1We thank an anonymous reviewer for this possible explanation.
Martin et al., 1994). How do these data correspond with our findings? In contrast to unimpaired control subjects, E.A. showed better recall performance for visually as compared to auditorily presented unrelated word lists (cf. Martin, 1990). In the diagnostic process, this inverted modality effect indicates, among other things, the selective impairment of the phonological STS (Martin, 1990). If an inverted modality effect indicates impairment of phonological STS, then, inversely, the appearance of a modality effect should also indicate that phonological STS is involved in an experimental task. Thus, the finding of a modality effect in sentence recall (when no distractor list followed the sentence) supports the assumption that phonological STS contributes to short-term sentence recall.

Together, these considerations lead to the general idea that sentences are processed at several different levels and along different informational aspects (such as phonological, lexical, syntactic, and conceptual information), all of which might be used as retrieval cues in sentence recall if available. Even if conceptual information is the central goal of sentence processing, and this fact has been ignored for quite some time, the contribution of the other informational aspects and particularly of phonological information should not be neglected if short-term sentence recall is studied.

APPENDIX

Sentences and Lure Words (in Parentheses) Used in Experiment 1
(German Originals and English Glosses)

   The presentation (exhibition) of modern art in this museum contains some very extraordinary paintings.

2. Er erhob sich von seinem Stuhl (Platz), damit die alte Dame nicht länger stehen musste.
   He got up from his chair (seat) so that the old lady would not have to stand any longer.

3. Der Professor für Geschichte erwartete ungeduldig eine Erwiderung (Antwort) auf seine unerwartete Frage.
   The history professor waited impatiently for a reply (answer) to his unexpected question.

4. Die Mutter rollte die Brücke (Matte) zusammen und warf sie in den Wagen.
   The mother rolled up the rug (mat) and threw it into the car.

5. Der Lehrer (Trainer) begann die Übungen jeden Tag mit einigen Sit-Ups und Kniebeugen.
   The teacher (trainer) started the exercises every day with several sit-ups and knee bends.

6. Der Strauch (Busch) neben der Terrasse muß vor der Party noch geschnitten werden.
   The shrub (bush) next to the terrace needs to be trimmed before the party.

7. Die neuen Vorhänge im Zimmer der Gäste sind aus einem hellen Material (Stoff) angefertigt.
   The new curtains in the guest room are made of light material (fabric).

8. Der Feuerwehrmann wurde für seine Beherztheit (Tapferkeit) bei der Rettung hilfloser Kinder geehrt.
   The fireman was honoured for his courage (bravery) in saving helpless children.

9. Sie zogen in ihr neues Heim (Haus), eine Woche, nachdem er seine Arbeit begonnen hatte.
   They moved into their new home (house), one week after he had started his job.

10. Das Kanu glitt über den Teich (See), während der Mann nach Fischen Ausschau hielt.
    The canoe glided across the pond (lake) while the man kept a look out for fish.

11. Der Bericht wurde von vier Leuten geprüft, bevor der Irrtum (Fehler) bemerkt wurde.
    The report was checked by four people before the error (mistake) was noticed.

12. Der Ritter ritt um den Palast (Burg), um einen geeigneten Eingang zu suchen.
    The knight rode around the palace (castle) to look for just the right place to enter.

    They went down to the cellar (basement) and rummaged through some boxes of toys.

14. Bill bereitete das Gericht (Mahlzeit) für die Familie erst nach der Büroarbeit zu.
    Bill fixed supper (meal) for the family after his office-work was finished.

15. Die Wissenschaftlerin verwendete ein Sekret (Gift) von Schlangen bei ihrer Forschung über Gehirnfunktionen.
    The scientist used a secretion (poison) from snakes for her research on brain functioning.

16. Der Abend war kalt, deshalb zog er seine Weste (Jacke) an, bevor er zum Fußballspiel ging.
    The evening was chilly, therefore he put on his cardigan (jacket) before he went to the football game.
17. Die Boxer standen im Mittelpunkt (Zentrum) des Rings, während der Schiedsrichter gesprochen hatte. Although it did not really please her, she bought the flashy and colorful patterned seat (chair).

18. Er betrat das Lokal (Restaurant) und suchte nach dem zuvor telefonisch reservierten Tisch.

19. Sie stellten den Blumenstrauß pompöse auf einem damit ausgestatteten Spiegelsaal des Schlosses (castle).

20. Die Frau fragte den Autor (Schriftsteller), ob er ihr Exemplar seines neuen Buches signieren könne.

Sentences and Lure Words (in Parentheses) Used in Experiment 2 (German Originals and English Glosses)

1. Nach dem Tod des Kindes hatten der Familie viele Freunde Mitgefühl (Beileid) ausgesprochen.
2. Nachdem die Studentin die letzte Prüfung absolviert hatten, wartete sie ungeduldig auf das Resultat (Ergebnis).
3. Obwohl sie ihren Freund verlassen hatte, stellte sie kein Gefühl von Freiheit (Ungebundenheit) ein.
4. Wenn er allein und ungestört in seinem Atelier arbeiten konnte, hatte er die besten Einfälle (Ideen).
5. Seit die Ärztin als Kind beinahe ertrunken war, hatte sie große Angst vor dem Meer (Ozean).
6. Sobald Peter mit der Schule fertig war, wollte er eine Ausbildung als Schreiner (Carpenter) beginnen.
7. Die Großmutter hatte für ihre Enkel stets eine Dose mit Keksen (Plätzchen) im Schrank.
8. Nachdem die Möbelpacker alles im Wohnzimmer verstaut hatten, nahmen sie Platz auf einer Truhe (Kiste).
9. Es dauerte mehrere Monate bis zur endgültigen Fertigstellung ihres Heims (Hauses).
10. Obwohl es ihr nicht sonderlich gefiel, kaufte sie den auffälligen und bunt gemusterten Stuhl (Stuhl).

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