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Reading Comprehension in the Presence of Unattended Speech and Music

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This series of experiments investigated whether the detrimental effects of unattended speech that have been obtained in short-term memory tasks would be obtained in reading comprehension. Such effects would be expected if reading comprehension depends on the maintenance of phonological information in short-term memory. The first three experiments demonstrated that unattended speech but not music interfered with reading comprehension while unattended music had a greater interfering effect than speech on a music identification task. Experiments 4 and 5 showed that the detrimental effect of the speech backgrounds on reading was due to their semantic rather than their phonological properties. The failure to find a phonological interference effect argues against a role for phonological short-term memory in reading comprehension.

In reviews of the effects of background noise on human performance, Poulton (1977, 1979) concluded that the masking of representations of inner speech in working memory was one source of detrimental effects. In the experiments reported here we were specifically concerned with whether background noise of various types would impair reading comprehension. Such an effect would be expected if background noise does, in fact, mask inner speech, and if reading comprehension depends on the maintenance of speech representations in working memory. Evidence relevant to these two claims is reviewed below.

Studies that have directly examined the effects of a noise background on a verbal short-term memory task have found that with auditory presentation of the memory lists, impaired performance is obtained (Rabbitt, 1966, 1968); however, such effects might be attributed to the subjects having to devote most of their attentional capacity to perceiving the auditory signals presented in a noise background, with the result that less capacity is available for rehearsal. With visual presentation of the memory lists, one would still expect a detrimental effect of background noise if such

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noise disrupts inner speech, because subjects routinely recode visually presented verbal lists into a phonological form in short-term memory tasks (Conrad & Hull, 1964; see Crowder, 1976, for a review). With visual presentation, contradictory results have been obtained: some studies have documented impaired performance with a noise background (Millar, 1979; Salame & Wittersheim, 1978; Salame & Baddeley, 1982), while others have found no effect (Hintzman, 1965; Murray, 1965; Sperling, 1963). However, recent findings suggest that if a speech background rather than a broadband noise or tone background is used, reliable decrements in short-term memory may be obtained even with visually presented lists (Colle & Welsh, 1976; Salame & Baddeley, 1982). These effects apparently do not depend on the meaningfulness of the background because Colle and Welsh used a foreign language unfamiliar to the subjects and Salame and Baddeley found equally interfering effects for word and nonword backgrounds that were matched in terms of their component phonemes. Salame and Baddeley also found that phonemic similarity of the background to the words in the memory list rather than semantic similarity predicted the degree of interfering effect. Because phonological similarity of the background to the phonological representation of the memory list items predicts the size of the interfering effect on short-term memory tasks, only a small interfering effect might be expected with a non-speech noise background. Thus, the inconsistent results with white noise may reflect the difficulty in detecting a small effect.

The explanations offered by Colle and Welsh (1976) and Salame and Baddeley (1982) as to the locus of the background speech effect suggest that the speech interferes with an acoustic or non-articulatory phonological, rather than an articulatory, representation of speech. Colle and Welsh (1976) speak of the background speech as interfering with "auditory sensory memory" and Salame and Baddeley as interfering with a (non-articulatory) phonological memory. Of course, for the background to interfere with memory for visually presented list items, it must be the case that the items were transformed into an acoustic or phonological format. Also, because the background was unattended, it must be the case that these auditory backgrounds had obligatory access to this phonological store.

Several authors have argued that reading comprehension depends on the conversion of written words to their phonological representations, and storing these representations in short-term memory while the comprehension process takes place (Baddeley, 1979; Kleiman, 1975; Levy, 1975; Slowiaczek & Clifton, 1980). The evidence supporting this contention has often come from dual task paradigms in which the subject performs a reading task while carrying out a secondary task (such as repeating an irrelevant word subvocally) that presumably interferes with phonological storage of the written material. The assumption that articulatory suppression interferes with a phonological memory code derives from results of short-term memory studies showing that for visually presented lists, articulatory suppression eliminates the effect of phonological confusability (Murray, 1967, 1968).

A series of studies on reading using this articulatory suppression paradigm was carried out by Levy (1975, 1977, 1978). In her earlier experiments, subjects were presented with a small set of sentences and then had to decide if test sentences were identical to those presented or had been changed in any way. (The changes included substitutions of a synonym or an exchange in the position of two nouns.) Under these conditions, detrimental effects of articulatory suppression were generally obtained. Levy (1975) concluded that articulatory suppression prevented the development of an acoustic code that was necessary to provide a means of holding the written input until it was understood. Later results, however, forced a modification of this conclusion. In the later study (Levy, 1978), a paraphrase task was introduced in which subjects were asked to determine whether test sentences accurately paraphrased the meaning of the original. On this task, no effect of suppression was obtained. Levy (1978) concluded that articulatory suppression prevented the development of a code that was important for verbatim recall of sentences but not for sentence comprehension.

In contrast to Levy's results, other studies have documented interfering effects from articulatory suppression on reading tasks that required comprehension and did not require verbatim recall (Baddeley, Eldridge, & Lewis, 1981; Kleiman, 1975; Slowiaczek & Clifton, 1980). However, it is difficult to determine whether the detrimental effects reported in these studies derived specifically from phonological interference or from a more general attentional drain that results from doing two tasks simultaneously (Margolin, Griebel, & Wolford, 1982; Waters, Komoda, & Arbuckle, 1985). Waters et al. (1985) evaluated the effects of several secondary tasks on reading comprehension. After using a statistical adjustment procedure to control for the general processing capacity demanded by the different secondary tasks, they found no specific interfering effect for secondary tasks that involved phonological coding.

Several studies have used other types of methodologies for examining phonological effects in sentence reading by examining whether phonological properties of the words in the sentences affect performance. For example, Baron (1973) and Coltheart, Laxon, Rickard, and Elton (1986) requested subjects to make sentence acceptability judgments on sentences that contained homophones that were either correct in the sentence (e.g., "haul the load") or homophones of words that would be correct (e.g., "tie the not"). Both studies found poorer performance on the homophone sentences than on the control sentences. It should be noted, however, that in both studies the homophone effect occurred only on the anomalous sentences.[1] If the phonological store is involved in normal reading, one would have expected an effect on the plausible sentences as well. It is possible that a phonological or articulatory memory representation only becomes involved when some type of checking process is invoked to verify that an anomaly has occurred.

One study that did find an effect on both acceptable and anomalous sentences was carried out by McCutcheon and Perfetti (1982). They found longer reading times for tongue-twister sentences (i.e., sentences with repeated initial consonants or consonantal features) than neutral sentences. Although McCutcheon and Perfetti suggest a memory-related role for phonological codes, specifically that the phonological codes that are activated automatically when reading are retained for possible reaccess of lexical entries, it is not clear that a memory account is required. It is possible that the longer reading times resulted because subjects were internally vocalizing the sentences, and tongue-twister sentences take longer to say than control sentences. If it could be shown that the size of the tongue-twister effect related to the extent to which sentences required the reaccess of lexical entries (for example, by including garden path sentences or sentences employing anaphoric pronouns), such would constitute stronger support for their hypothesis.

In sum, the existing literature does not provide unequivocal support for a role for phonological memory in reading comprehension. The present study addresses this

[1] A homophone effect was obtained in the Coltheart et al. (1986) study on the acceptable sentences for the children included in the study, but not for the skilled adult readers.

issue by assessing the effects of irrelevant auditory backgrounds on reading comprehension. The subjects' task was to read coherent passages and then answer questions on their content. Unlike the dual task paradigms discussed above, the subjects were not required to do anything with the auditory backgrounds, and were, in fact, instructed to ignore them. However, if speech backgrounds have obligatory access to a phonological store as has been argued on the basis of the memory studies, one would expect such backgrounds to interfere with phonological storage of the material being read. In order to demonstrate that any interfering effects are in fact due to phonological interference, it would have to be shown, as in the memory studies, that the phonological properties of the background predict the degree of interference.

It should be emphasized that although the motivation for the present study derived from results on short-term memory performance, we were not concerned here with short-term memory for prose materials, but rather with comprehension. In fact, in the experiments reported here, subjects performed a letter detection or anagram task between reading and answering questions on a passage. The interpolated task should have served to wipe out any short-term memory representation of the passages. Subjects were not tested for verbatim memory of the material but rather asked questions about the content. The connection to the memory research is that phonological short-term memory has been proposed as a buffer for holding the verbatim representation of the sentence while the meaning is derived. If this view is correct, then interfering with phonological short-term memory should disrupt comprehension and result in impaired performance on tests of comprehension.

A few previous studies have examined the effects of irrelevant auditory backgrounds on reading comprehension. However, these studies have not been designed to assess whether the speech qualities of the background determined the degree of disruption. Detrimental effects have been found for music backgrounds (Fogelson, 1973; Henderson, Crews, & Barlow, 1945) and for noise backgrounds (Zimmer & Brachulis-Raymond, 1978). In some cases, the music backgrounds contained lyrics. For example, Henderson et al. (1945) found that performance on a paragraph reading test decreased significantly when subjects were exposed to popular music containing lyrics, but found no difference between a classical music background and silence. From their study it is impossible to determine whether it was the presence of the lyrics or the different types of music that led to the detrimental effect of the popular music. In a study that found greater detrimental effects on reading for an industrial noise background than for speech or music backgrounds (Zimmer & Brachulis-Raymond, 1978), the noise was presented in intermittent bursts. Thus, it is likely that each burst caused an orienting response by the subject, and consequently caused the subject to spend less time on the reading task than subjects who were reading in quiet. In contrast to the noise, the speech and music backgrounds were continuous.

All the backgrounds in the present experiments were equated for intensity and sound output, and, except where noted, all were continuous. The first study reported below compared the effects of speech, white noise, and instrumental music backgrounds on reading comprehension. If the background auditory inputs simply served to distract the reader's attention from the material being read, one might expect similar degrees of interference from all of the backgrounds since all were continuous. If reading comprehension does depend on the retention of phonological information, one would expect greater interference from the speech than from either the noise or instrumental music conditions. Given that white noise has sometimes been shown to disrupt short-term memory performance one might expect that an instrumental music condition (without lyrics) would have a perhaps small, but still disruptive effect on reading comprehension.

As indicated above, the existing literature is equivocal with regard to the effect of music since some studies have found no effects of background music (Zimmer & Brachulis-Raymond, 1978), while some that have found effects have employed music with lyrics (Henderson et al., 1945). It is possible that instrumental music might have effects that differ from both speech and white noise backgrounds. Music is a structured input like speech and differs from white noise in this regard. Perhaps meaningfully structured inputs are processed mandatorily to a greater degree than unstructured inputs and the processing devoted to these inputs takes away from resources that could be devoted to the reading tasks. However, at least some aspects of music appear to be processed quite differently than speech, as a left ear advantage has been reported for the recognition of dichotically presented melodies, while a right ear advantage has been found for dichotically presented digits (Kimura, 1964). It is possible that instrumental music alone, if it engages processes very different from those involved in language, would have no detrimental effect on reading.

EXPERIMENT 1

In the present experiment, two types of speech backgrounds were used—a prose passage and a random word list. In constructing these backgrounds, the prose was spoken in a continuous fashion and the random word list was read at approximately the same rate as the prose. The list of words was constructed by randomizing the words from the passage. Thus, any differences in the effects of the two backgrounds could not be attributed to differences in speech rate or differences in the words employed, but would have to be attributed to the greater syntactic and semantic coherence of the prose background.

In addition to the quiet condition, three non-speech auditory background conditions were employed: white noise, instrumental music, and random tones. None of these backgrounds would be very similar acoustically to the speech, and thus one might expect at most a small interfering effect from these backgrounds based on the short-term memory results. On the other hand, if structured inputs demand processing, then one might also expect to find large interfering effects from both speech and music, but not from random tones or white noise.

Method

Subjects. Thirty-six subjects from Rice University undergraduate psychology courses participated in the study for extra credit. All subjects were native English speakers. Subjects participated in groups of one to six.

Materials and apparatus. Six passages dealing with varied topics from a practice Graduate Record Examination (GRE) book (Brownstein, Mitchel, & Hilbert, 1982) were given to subjects to read under six auditory conditions. The topics of the six passages were the evolution of mammals, sound propagation, geology, physical metallurgy, the creative process, and Francis Bacon's "Of Studies" essay. Each test on the passages consisted of multiple choice and cued recall/short-answer type questions. Additional questions supplemented some of those taken from the practice GRE book.

The instrumental music used in this experiment was a jazz–rock song "Dance with Me" written by Johanna and John Hall from an album "Finger Paintings" by Earl Klugh (Blue Note BN-LA737-H). The random tone condition was a 4 note computer generated random sequence at a rate of 90 tones per minute.

The stimulus material for the continuous verbal speech was a tape recording of a female reading sections of a passage unrelated to those that were to be studied during the experiment. This passage dealt with the coloring of insects. The passage was read at a fairly fast rate. For the other verbal speech condition, the same female read words that were taken from the insect coloration passage, but were listed in a randomly arranged order. These words were read at approximately the same rate as the continuous verbal speech condition.

A tape of white noise was made from a white noise generator (Lafayette Instrument Company, Model Number 15011). All auditory conditions, except for the quiet condition, were equalized at the time of recording for overall power amplitude using slow averaging V.U. meters. The sound level for all auditory conditions (except for the quiet condition) was approximately 82 decibels (dB). The onset and offset for each condition was signaled by a tone. The duration of each auditory condition was 210 s.

Procedure. At the beginning of the experiment subjects were informed that there were two tasks to complete: a series of reading comprehension tests and a series of letter and number search tests. Subjects were told to read and comprehend as much of each passage as possible. They were told that during the reading task one of several types of noise conditions would be played but that they were to ignore the backgrounds and concentrate on the reading task since they would be asked to answer questions about each passage. Subjects read passages under six auditory conditions: continuous spoken speech, randomly arranged speech, instrumental music, random tones, white noise, and quiet. Three minutes were allowed for each passage. Immediately following the reading of each passage and prior to the beginning of each passage test, subjects were asked to search for 30 s for two letters or numbers on a typed sheet that was completely filled with letters and numbers. This letter and number search task served as the interpolated task between the reading of each passage and its test.

Immediately following the search task, subjects were then presented with questions concerning the last passage read. Subjects were allowed 4 min to complete each set of questions as best they could. All subjects were always tested under quiet conditions and did not have the passages to reread. Each subject participated in all six auditory conditions. The order of conditions and the passages were balanced with two Latin squares.

Results

Because of differences in the difficulty of the different passages, raw test scores were transformed into z-scores for each passage in order to reduce the variance of the scores in the different background conditions. The experimental design was a single factor of 6 auditory conditions: continuous spoken speech, randomly arranged speech, instrumental music, random tones, white noise, and quiet. Table 1 shows reading comprehension performance as a function of these auditory conditions. Both the mean z-scores and the mean percent correct are given. A one-way repeated measures analysis of variance yielded a significant effect of the auditory conditions, $F(5,175) = 2.56$, $MS_e = .501$, $p < .05$. Comparisons of each of the auditory background conditions against the quiet condition revealed significantly poorer performance in the continuous speech and randomly arranged speech conditions, $t(35) = 2.38$, $p < .05$ and $t(35) = 2.10$, $p < .05$, respectively. None of the other comparisons against the quiet condition reached significance. Although mean performance was poorer in the continuous speech than the randomly arranged speech condition, the comparison of the continuous speech versus the random words condition failed to reach significance, $t(35) < 1.0$. Pairwise comparisons of the instrumental music,

TABLE 1
MEAN READING COMPREHENSION PERFORMANCE AS A FUNCTION OF AUDITORY CONDITIONS IN EXPERIMENT 1

	Auditory conditions					
	Continuous speech	Random speech	Instrumental music	Random tones	White noise	Quiet
z-score	−.272	−.167	.189	−.028	.112	.165
Percent correct	62.6	65.2	72.3	67.2	70.4	72.1

random tones, and white noise conditions failed to show any significant differences between these three conditions (all p's $>$ .10).

Discussion

This experiment demonstrated that significant impairments in reading comprehension performance were obtained with speech but not non-speech backgrounds. A slightly greater decrement was found for the meaningful continuous speech background that the random word condition, but this difference was not significant. This result indicates that speech backgrounds need not draw on deeper levels of syntactic and semantic processing to have a disruptive effect. The failure to find an interfering effect for the instrumental music background indicates that not all meaningfully organized auditory backgrounds will interfere with the performance of a reading task.

EXPERIMENT 2

The results of the first experiment that showed no detrimental effect from an instrumental background suggest that the previously reported detrimental effect of a popular music background on reading comprehension (Henderson et al., 1945) might have been due to the presence of lyrics. This second experiment directly addressed this question by assessing analytically the contributions of the verbal and musical aspects of a background to the disruption of reading comprehension. The overall design was a factorial combination of two factors: an instrumentation factor (instrumentation versus no instrumentation) and a verbal factor (sung lyrics versus spoken lyrics versus no lyrics). Both spoken and sung lyrics were included in order to assess whether the musicality of sung lyrics (i.e., the changes in pitch and exaggeration of vowel duration) might mediate the degree of disruption for reading comprehension. Besides providing an assessment of the effects of sung lyrics, the instrumentation and spoken speech conditions of the present experiment would allow for a replication of the findings obtained in Experiment 1.

Method

Subjects. Thirty-six male and female subjects from the Rice University community participated for either $4.00 or for extra credit toward an introductory psychology course. All subjects were native English speakers. Subjects participated in groups of one to six.

Materials and apparatus. The same passages employed in Experiment 1 were used here, although some of the test questions were different.

The music used in this experiment was a popular song "You Light Up My Life" written by Joe Brooks. The instrumental arrangement was taken from the original movie soundtrack (Arista AB4159). Although the record album also included a mixed lyrical and instrumental version of the song, it was not used in this experiment. For this experiment, a female undergraduate soprano vocalist from Rice University's Shepherd School of Music both sang and spoke the lyrics. The onset of the words in the spoken lyrics condition corresponded closely with the onset of the corresponding words of the sung version. However, to maintain natural word pronunciation in the spoken lyrics condition, the offset of each word did not necessarily correspond with the offset of the words in the sung lyrics condition. The song was recorded and mixed on two reel-to-reel tape decks and was later transferred to a cassette deck for playback. All auditory conditions (except for the quiet condition) were equated for overall sound amplitude using slow averaging V.U. meters at the time of recording; they were played back at the same volume setting. The sound level for all auditory conditions (except for the quiet condition) was approximately 82 dB. The amount of time allowed for study under each auditory condition was 3 min.

Procedure. The procedure was identical to that used in Experiment 1 with the exception that the auditory backgrounds were not present during the interpolated letter and number search task.

TABLE 2
MEAN READING COMPREHENSION PERFORMANCE IN EXPERIMENT 2 AS A FUNCTION OF THE AUDITORY FACTORS: INSTRUMENTAL AND LYRICS

	Sung lyrics	Spoken lyrics	No lyrics	Mean
Instrumental	−.208	.069	.290	.050
	(60)	(65)	(69)	(65)
No instrumental	.009	−.343	.183	−.050
	(63)	(57)	(67)	(62)
Mean	−.100	−.137	.237	
	(62)	(61)	(68)	

Note. Standardized by passage; percent correct shown in parentheses.

Results

As in Experiment 1, raw test scores for a given passage were converted to z-scores for that passage. Table 2 shows mean z-scores and mean percent correct on reading comprehension as a function of the instrumentation and verbalization factors. With regard to the instrumentation factor, performance was slightly better in the instrumentation condition than in the no instrumentation condition; however, this difference was not significant, $F(1,35) = 1.36$, $MS_e = .400$, $p > .10$. A significant effect was obtained for the different lyrics conditions, $F(2,70) = 3.59$, $MS_e = .849$, $p < .05$. More specifically, a contrast of the sung lyrics and spoken lyrics conditions against the no lyrics condition showed significantly poorer performance for the lyrics conditions. This contrast accounted for 99% of the variance among the means for the lyrics conditions. The effect of sung lyrics did not, however, differ from the effect of the spoken lyrics.

The interaction of the instrumentation and lyrics factors was marginally significant, $F(2,70) = 2.48$, $MS_e = .718$, $.05 < p < .10$. An examination of the means in Table 2 show that in the no lyrics condition, performance in the instrumental condition was slightly, but nonsignificantly better than in the no instrumentation (i.e., quiet) condition, $t(35) = .263$. In the remaining four conditions, sung lyrics were marginally more detrimental than spoken lyrics when instrumentation was present, $t(35) = 1.76$, $.05 < p < .10$, while spoken lyrics were more detrimental than sung lyrics when instrumentation was absent, $t(35) = 2.84$, $p < .01$.

Discussion

In this experiment employing a popular, familiar musical selection, there was no evidence that an instrumental background alone caused a decrement in reading comprehension performance. In fact, in the no lyrics condition, as well as across all of the lyrics conditions combined, performance was slightly higher with the instrumental background that without it. In contrast, a decrement in performance was found when the background contained verbal material, whether spoken or sung. The absence of a difference between the sung and spoken lyrics when collapsing across instrumentation conditions implies that the musicality of the sung lyrics did not affect the size of the decrement in either a positive or negative fashion.

The marginally significant interaction between the lyrics and instrumentation conditions is somewhat puzzling. If similarity of the background to a phonological form generated during reading predicted the size of the interfering effect, one might have expected spoken lyrics to be more detrimental than sung lyrics whether or not instrumentation was present. Although spoken lyrics caused worse performance than sung lyrics in the no instrumentation condition, sung lyrics caused marginally worse performance than spoken lyrics in the instrumentation condition. One qualifying factor that should be kept in mind in interpreting these results is that when instrumentation was absent, the spoken lyrics condition was discontinuous while the sung lyrics condition was continuous. This was the case because the onset of the words in the spoken lyrics was timed to be the same as the onset of the same words in the sung lyrics condition. As discussed in the introduction, discontinuity is distracting because changes in the sound level of the background may cause an orienting response. In Experiments 4 and 5, different types of continuous backgrounds are used to provide further evidence on whether phonological properties of the background determine the size of the interfering effect.

In sum, for this music selection, only the verbal aspect of the background had any disrupting effect on reading comprehension performance. However, the question remains as to whether the backgrounds are interfering with a phonological representation of the written passages. Two other possibilities were investigated in the subsequent experiments. First, it is possible that a speech background attracts more attention than other types of auditory backgrounds, no matter what the primary task. That is, speech may have some priority for humans that causes it to intrude into consciousness and thus disrupt the processing of any other input whether verbal or nonverbal. This possibility was investigated in Experiment 3 by comparing the effects of the continuous speech and music backgrounds on a primary task that involved music identification. Second, since even the random word condition from Experiment 1 contained meaningful words, it is possible that the verbal backgrounds are interfering with some type of semantic rather than phonological representation. This possibility was investigated in Experiments 4 and 5 by assessing the effects of meaningless speech backgrounds on comprehension.

EXPERIMENT 3

In this experiment, the subject's primary task was to identify familiar songs on the basis of viewing short excerpts from musical scores (i.e., printed musical notation). Although subjects were not given specific instructions on how to carry out this task, it was expected that they would internally translate the written form into a sung version in order to identify the melodies. (The subjects were all music majors.) The excerpts were not taken from the beginning of the song in order to avoid the possibility that subjects could identify the song simply on the basis of familiarity with the visual appearance of the first few bars.

Subjects carried out this task under three auditory background conditions: quiet, music, speech. If speech backgrounds simply demand more attention than other auditory backgrounds no matter what the primary task, then the speech background should again have the greatest detrimental effect on this primary task involving music identification. On the other hand, if similarity of the background to the representations employed in the primary task is the crucial factor, then greater interference for the music background would be expected.

Method

Subjects. Thirty-four students of the Shepherd School of Music at Rice University participated in the study. However, only 24 were able to identify the two excerpts that were given as a test for inclusion in the study. The average time spent studying music was 8.7 years and ranged from 4 to 25 years. The subjects were evenly distributed between vocal and instrumental majors.

Materials. Three pages, each containing seven short excerpts of three to four bars, were constructed. All excerpts were taken from the Norman Rockwell Family Songbook (1984).

The music background was the instrumental jazz–rock song used in Experiment 1, "Dance with Me" written by Johanna and John Hall from the album "Finger Paintings" by Earl Klugh (Blue Note BN-LA737-H). The speech background, which was also used in Experiment 1, was a female reading a passage concerned with the coloring of insects. The backgrounds were tape recorded on a cassette deck and had a duration of 3½ min. The onset and offset for each condition was signaled by a tone.

Procedure. In order to be included in the study, subjects had to identify two visually annotated excerpts presented in quiet. Subjects who met this criterion were given booklets containing the three pages of seven excerpts each. They were told that they would be identifying further examples under different auditory conditions. When they heard a tone, they were to turn the cover page and attempt to identify the seven excerpts on the following page within 3½ min. If they finished before the allotted time, they were instructed to not turn the page until told to do so. Subjects wrote their answers on a numbered sheet.

All subjects participated in the three auditory conditions. The order of the three pages of musical excerpts was constant. The presentation order of the three backgrounds was counterbalanced across subjects using a Latin square.

Results

Mean percent of songs correctly identified for the three background conditions is shown in Table 3. Raw scores were converted to *z*-scores by page of excerpts in order to adjust for the difficulty of the different pages. Mean *z*-scores are also shown in Table 3. As can be seen in the table, performance was best in quiet, worst with the music background condition, and intermediate for the speech background. An analysis of variance on the *z*-scores found a main effect for background, $F(2,46) = 23.61$, $MS_e = .3338$, $p < .001$. All pairwise comparisons of the backgrounds were also significant at the .001 level: $t(23) = 8.18$ for music and quiet, $t(23) = 3.70$ for speech and quiet, and $t(23) = 3.25$ for music and speech.

Discussion

For this task involving melody recognition from a visual representation, an irrelevant music background had a greater detrimental effect on performance than an irrelevant speech background. An opposite pattern was obtained with the same backgrounds for the reading comprehension task in Experiment 1. The contrast between the results for Experiments 1 and 3 indicates that the larger effect of the speech than music background in Experiment 1

TABLE 3
MEAN PERFORMANCE ON MELODY IDENTIFICATION AS A FUNCTION OF AUDITORY BACKGROUND CONDITION IN EXPERIMENT 3

	Quiet	Music	Speech
z-score	.609	−.604	−.005
Percent correct	65.5	26.8	46.4

could not be attributed to some property of speech that makes it more interfering than music no matter what the primary task.

The results of the first three experiments taken together imply that the speech and music auditory backgrounds demanded some mandatory processing, and the mandatory processing of the backgrounds selectively interfered with completion of a task that involved similar processing. One might question why the instrumental backgrounds had no interfering effect on the reading comprehension tasks, while the speech background had a significant interfering effect on the melody identification task. A possible explanation is that the reading comprehension task did not involve music processing in any way, while the melody identification task did have a verbal component. That is, subjects were required to write down the names of the songs they could identify. Also, all of the songs had familiar lyrics, and the subjects may have been singing the words to themselves in order to remember the names of the songs.

EXPERIMENT 4

Although the first two experiments demonstrated a detrimental effect for speech backgrounds on reading comprehension, interesting questions remain as to what aspect or aspects of the background speech were causing the interference. That is, in both experiments, the background speech had both phonological and semantic components and it is possible that either or both of these components caused the interference. Experiments 4 and 5 were designed to assess the contributions of these components to the interfering effect.

Studies of short-term memory for visually presented words that have employed an unattended speech background have found that the phonological rather than semantic properties of the background cause interference with memory performance. Colle and Welsh (1976) found a significant interfering effect from a foreign language background on short-term memory performance. Moreover, the background eliminated the effect of phonological similarity on memory performance. Salame and Baddeley (1982) found that non-word backgrounds interfered with memory performance more than did white noise, but that words that were identical to the memory set items had no greater interfering effect than words that were phonologically similar to the memory set items but were semantically distinct. These studies concluded that the background interfered with acoustic or phonological representations in short-term memory but not with semantic representations.

To the extent that reading comprehension depends on maintaining phonological representations of the written words in short-term memory as some researchers have argued (Baddeley, Lewis, & Vallar, 1981; Kleiman, 1975; Slowiaczek & Clifton, 1980), one might expect interference from semantically empty speech backgrounds. However, there are reasons for believing that meaningful speech backgrounds might cause greater interference than meaningless speech backgrounds. In reading comprehension, the goal is to understand the material and thus one would expect that the subject is carrying out a much greater degree of semantic processing than would be the case in a short-term memory task in which subjects appear to rely on the phonological rather than the semantic properties to maintain the memory items. Previous evidence indicates that subjects process unattended speech backgrounds to the level of meaning (Eich, 1984; MacKay, 1973). Thus, it is possible that the interfering effects obtained in Experiments 1 and 2 were due to semantic interference alone or to a combination of semantic and phonological interference.

In this experiment, the effect of a Russian prose background was compared to that of an English prose background. A white noise condition was also included to make it possible to determine if the Russian background would have a greater interfering effect than an auditory background containing no phonological features.

Method

Subjects. Forty-eight undergraduate students from Rice University participated in this study. All participated in order to obtain extra credit in a psychology class they were taking. None of the subjects could speak or understand Russian.

Materials. Eight passages were taken from the set of 36 passages that had been scaled for difficulty of comprehension by Miller and Coleman (1967). (This source of passages was also used in a study by Waters et al., 1985.) The eight passages were among those rated the most difficult. Six questions requiring short answers were made up for each passage that tested subjects' comprehension of the material. The passages were grouped into four sets of two each.

The background materials included a tape recording of a man reading a newspaper article in English, and a tape recording of the same man reading a newspaper article in Russian. The white noise background was created in the same fashion as that used in Experiment 1. These backgrounds were presented at approximately 82 dB.

Design and procedure. Each subject participated in four background conditions—the English, Russian, white noise, and quiet conditions. The order of the background conditions and the order of the passages were balanced using two Latin squares.

Subjects were given 1½ min to read each of the passage pairs, 45 s for each passage. At the end of the 1½ min, subjects attempted to solve 10 anagrams. They were given 3 min for the anagram test. Following the anagrams, they were given 3 min to answer 12 questions on the passages, six of which pertained to each passage. The auditory backgrounds were presented only during the time allowed to read the passages.

Subjects were tested in small groups of from one to four subjects.

Results

Raw scores on the passage questions were converted to z-scores by passage. Table 4 shows the mean z-scores and mean percent correct for the different backgrounds. The main effect of background was significant, $F(3,141) = 6.01$, $MS_e = .513$, $p < .001$. Performance in the English background condition was significantly worse than in any of the other conditions: $t(47) = 4.26$, $p < .001$ for English versus quiet, $t(47) = 2.55$, $p < .05$ for English versus white noise, and $t(47) = 2.30$, $p < .05$ for English versus Russian. Performance in the Russian background condition did not differ significantly from the white noise condition, $t(47) < 1.0$, but was significantly worse than performance in the quiet condition, $t(47) = 2.06$, $p < .05$. Performance in the white noise condition was not significantly worse than in the quiet condition, $t(47) = 1.44$, $p > .10$.

Discussion

The interfering effect of the English background was greater than that of the Russian background. Thus, the English passage had an effect on reading comprehension that could not be attributed to phonological interference but would have to be attributed to the meaningfulness of the

TABLE 4
MEAN PERFORMANCE ON READING COMPREHENSION AS A FUNCTION OF AUDITORY BACKGROUND CONDITION IN EXPERIMENT 4

	Quiet	Noise	English	Russian
z-score	.253	.137	−.357	−.033
Percent correct	69.4	67.3	57.8	63.8

background. A purely phonological interfering effect was unclear in the present results since although the Russian background caused performance to decline below that observed in the quiet condition, the difference between the white noise and Russian conditions did not approach significance. These results contrast with those obtained with irrelevant speech backgrounds on short-term memory performance where semantically related and unrelated backgrounds were found to have equally detrimental effects on performance and where nonword backgrounds were found to have a greater interfering effect than a noise background (Salame & Baddeley, 1982).

A possible problem with the present experiment is that the Russian background may have been sufficiently phonologically distinct from English such that the phonological interference effect was reduced. The next experiment used a series of nonwords as one of the backgrounds in order to have a meaningless background that had the phonological properties of English. Also included for comparison were a random word condition and a white noise condition. The random word condition was used rather than a prose condition in order to replicate the finding from Experiment 1 indicating that the speech background did not have to be composed of sentences in order to interfere with reading comprehension. The white noise condition was again included to determine if the nonword condition would have a greater interfering effect than a background that contained no phonological features.

EXPERIMENT 5

Method

Subjects. Forty-eight undergraduate students at Rice University participated in the study in order to obtain extra credit for psychology courses they were taking.

Materials. The passages and questions used in Experiment 4 were used here.

A random word list was created by randomizing the words from a newspaper story. The non-word condition was created by using a different random order of the same words, and changing one letter of each word to create a non-word. Both lists were read aloud in a continuous fashion and tape-recorded to create the random word and non-word background materials. The white noise background was created in the same fashion as that used in Experiment 1. All of the auditory backgrounds were presented at approximately 82 dB.

Design and procedure. The design and procedure were identical to those in Experiment 4 with the exception that the four background conditions were random words, non-words, white noise, and quiet.

Results

As before, the raw scores on the passage questions were converted to z-scores by passage. Table 5 shows the mean z-scores and mean percent correct for each background condition. The main effect of background was significant, $F(3,141) = 7.78$, $MS_e = .5212$, $p < .001$. Performance in each of the auditory background conditions was significantly worse than in quiet: $t(47) = 4.59$, $p < .001$ for random words against quiet, $t(47) = 2.75$, $p < .01$ for non-words against quiet, and $t(47) = 2.91$, $p < .01$ for white noise against quiet. As is evident in Table 5, there was little difference between performance with a white noise background and performance with a non-word background, $t(47) = .37$, $p > .5$. However,

TABLE 5
MEAN PERFORMANCE ON READING COMPREHENSION AS A FUNCTION OF AUDITORY BACKGROUND CONDITION IN EXPERIMENT 5

	Quiet	White noise	Non-words	Words
z-score	.380	.023	−.038	−.365
Percent correct	67.5	60.2	59.2	51.9

the random word condition impaired performance more than the non-word condition, $t(47) = 2.01, p < .05$, and more than the white noise condition, $t(47) = 2.38, p < .05$.

Discussion

The results of this experiment were similar to those of Experiment 4 in that a sequence of meaningful words had a greater interfering effect than a meaningless speech background, while the meaningless speech background did not interfere more than a white noise background. The failure to find a significant difference between the non-words and the white noise condition indicates that the phonological component of the background speech interference effect is minimal, if it exists at all. These results are quite different than those obtained by researchers using auditory backgrounds during a short-term memory task with visually presented items. If the background speech materials were interfering with phonological storage of the written words, one would have expected the pattern obtained in short-term memory experiments to be found here, that is, greater interference for non-word speech backgrounds than noise backgrounds.

The greater interference for the meaningful speech than the non-words again supports the view that interference is occurring at the level of semantic processing. It might be objected that greater interference for meaningful words occurred because processing words demanded more capacity than processing non-words, and not because of some specific semantic interference. If so, then one would also expect greater interference from words than non-words when the primary task is serial recall; however, Salame and Baddeley (1982) found equally interfering effects for word and non-word backgrounds on a serial recall test. The different pattern of interfering effects when the task is reading comprehension or serial recall implies that the degree of interference depends on the overlap between the processing required by the primary task and the processing demanded by the background. Further comment on this issue is presented in the General Discussion.

General Discussion

The detrimental effect of unattended speech on short-term memory performance for visually presented items has been attributed to a disruption of phonological storage because the degree of disruption depends on the phonological properties of the background. The intent of the present study was to determine if a similar pattern of detrimental effects from unattended speech would be obtained in a reading comprehension task. If so, these findings would support a role for phonological retention in reading comprehension. The results of this series of experiments showed that although decreased reading comprehension scores were obtained with speech backgrounds, the degree of disruption depended on the semantic rather than the phonological properties of the background. The disruption obtained from a non-word background was no greater than that from a noise background.

It might be argued that the equivalent degrees of disruption from non-words and white noise occurred because white noise also disrupts phonological storage, as has been argued by Poulton (1979). However, the basis for claiming that the unattended speech effect on short-term memory tasks was due to a phonological memory disruption was that greater effects were found for speech than for white noise (Salame & Baddeley, 1982, 1983). It would be hard to see why non-words and white noise should have equivalent effects on phonological memory since non-words have phonological properties while white noise does not.

The failure to find a phonological interference effect on the reading task implies that reading comprehension does not depend on the phonological short-term memory that has been identified from research on serial recall. These results concur with those of Waters et al. (1985) who controlled for the general capacity demands of different secondary tasks and found no specific interfering effect for tasks that involved phonological coding. As in the present experiments, they did find a semantic effect. That is, they found that secondary tasks that involved processing the meaning of words did have a specific interfering effect on reading comprehension.

Waters et al. concluded that previous studies that had reported a phonological interference effect from secondary articulatory tasks had not adequately controlled for the general capacity drain of the secondary tasks. It is also possible that differences between the reading task used by Waters et al. and those employed in other studies contributed to their failure to find a phonological interference effect. In their study, as in the present experiments, the reading task was more like everyday reading in that subjects read coherent passages in order to extract their meaning. Several previous studies that have used a sentence acceptability task have found effects of articulatory suppression or effects of phonological properties of the words on only the anomalous sentences (Baddeley et al., 1981; Baron, 1973; Coltheart et al., 1986). As mentioned in the introduction, it is possible that phonological effects occur on the anomalous sentences because subjects mentally rescan a phonological representation of the sentence in order to verify that an anomaly has occurred. Such a rescanning procedure may not be involved in the reading of meaningful sentences.

The difference between the pattern of effects from speech backgrounds obtained from short-term memory experiments and that obtained in the present experiments would seem to be due to the nature of the task the subject is trying to accomplish in serial recall versus reading comprehension. In serial recall, the subject must retain the verbatim representations of the words and their order. A great deal of evidence indicates that subjects rely on a phonological code to accomplish this goal even when the words are presented visually. Although there is evidence that the semantic representations of the words in the memory sets are activated (Shulman, 1970), semantic similarity of the memory set items has been found to have only a negligible effect on recall while phonological similarity has a massive effect (Baddeley, 1966). In reading comprehension, the subject is not required to remember the verbatim content of the passage, but rather to understand its meaning. Thus, in the serial recall situation, the phonological properties of the background interfere with the phonological representation of the memory set items, while in the reading comprehension situation, the semantic properties of the background interfere with the meaning representation being developed for the material being read.

The different effects of the auditory backgrounds in the two situations would not have to be attributed to different processing of the backgrounds. It would be simpler to assume that the backgrounds are processed to the level of the meanings of the individual words whenever meaningful words are employed. In order to access the meanings of the words a phonological representation of the input would have to be derived from the acoustic signal. In serial recall tasks, since the subject is not relying on the semantic representations of the words to complete the task, the semantic properties of the background have no effect. In the reading comprehension task, the semantic properties of the background interfere with the meanings of the words being read. The fact that the phonological properties of the background speech did not appear to interfere with comprehension would indicate that maintaining a phonological representation of the written material in short-term memory is not an important prerequisite for arriving at the meaning representation.

Other interesting findings from this series of experiments relate to the effect of the music backgrounds on the reading and music tasks. The results from Experiment 3 indicate that music as well as speech is processed mandatorily and the results of this processing can interfere with an internally generated representation of a melody. The differential effects of the music and speech backgrounds on the music and speech tasks are consistent with numerous other findings indicating that speech and music engage very different processing mechanisms (see, for example, Allport, Antonis, & Reynolds, 1972; Ayres, Jonides, Reitman, Egan, and Howard, 1979; Kimura, 1964).

Taken as a whole, the results of these studies are consistent with theories of attention that assume that even to-be-ignored stimuli demand some types of processing and that the extent to which these processing demands will interfere with primary task performance will depend on the degree of overlap between the processing mechanisms and representations needed for completion of the primary task and those engaged by the distracting stimuli (Allport et al., 1972; Friedman & Polson, 1981; Navon & Gopher, 1979). With regard to the original question motivating these studies, the different pattern of interfering effects for speech backgrounds on reading compared to those obtained on short-term memory tasks argues against a role in reading comprehension for the maintenance of phonological information in short-term memory.

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