

Phonological Code Activation During Listening¹

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Rhyme priming to visually dissimilar rhymes (e.g., eight-late) was used in a lexical decision task to investigate the access and maintenance of speech-based codes in sentence comprehension. One member of the rhyme pair was embedded in a sentence and the other was presented visually for lexical decision. Rhyme priming obtained when the prime and target were separated by four but not by seven intervening words, suggesting that the phonological code for the word was initially accessed and then rapidly decayed.

Many aspects of the comprehension process probably require the listener to maintain information in working memory for the purpose of integration with other information. For example, the presence of long-distance dependencies may require information to be held in memory during parsing (Wanner & Maratsos, 1978) and maintaining selected information in working memory may be necessary for anaphora resolution as well as for integrating propositions and drawing inferences.

Numerous researchers have suggested that speech-based codes may

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serve an important role in maintaining linguistic information in working memory in both listening and reading (for a review see McCusker, Hillinger, & Bias, 1981). Some evidence in support of this claim comes from studies in which irrelevant vocalization is used to block speech recoding. For example, Levy (1977) had subjects count while listening to or reading sentence triples. Counting interfered with subject's ability to detect lexical and semantic changes in a subsequently presented sentence in the reading but not the listening condition. More recently, however, Levy (1978) and Slowiczek and Clifton (1980) have suggested that blocking speech coding interferes with only higher-level discourse processes such as integrating propositions and drawing inferences. Slowiczek and Clifton found that irrelevant vocalization interfered with higher level processes in both listening and in reading, although the effect was more robust in reading. These results suggest that speech recoding is used primarily for discourse-level integrative processes.

However, another interpretation of these findings has been pointed out by Levy (1977) and by Waters, Komoda, and Arbuckle (1985). If we make three reasonable assumptions: (1) reading is a more resource demanding task than listening; (2) vocalization draws on limited capacity processing resources; and (3) higher-order processing is more resource demanding than lower-level processing, then it is possible to account for the pattern of results obtained by Slowiczek and Clifton (1980) without appeal to the notion of speech coding. Vocalization simply interferes more with processes that draw heavily on limited capacity resources than it does with processes that are less resource demanding.

In view of these considerations, it becomes important to explore other methodologies that might provide converging evidence about the role of speech-based codes in comprehension. "Rhyme priming" may be one such methodology. Meyer, Schvaneveldt, and Ruddy (1975) demonstrated that lexical decisions to a visually presented word are facilitated when the word is preceded by a rhyming word. For example, lexical decisions to *couch* are facilitated when it is preceded by *pouch*. Hillinger (1980) demonstrated that cross-modal rhyme priming obtains in the lexical decision task when the prime is presented auditorily and the target word is presented visually. Tanenhaus, Flanigan, and Seidenberg (1980) found similar results using a color naming task. In both of these studies rhyme-priming obtained even when prime and target were spelled differently.

The present study attempted to use rhyme priming to trace the availability of phonological codes for words in sentences. The purposes of the study were two-fold. The first was to determine whether or not rhyme priming would obtain when the prime word was embedded in a

sentence. The second was to examine two variables that might affect the availability of the phonological code for a word. The first variable was time. It seems likely that phonological codes for words might decay shortly after they are accessed. This hypothesis was investigated by varying the number of words that intervened between a prime word embedded in a sentence and a target word presented at the end of the sentence. The second variable was whether the prime word occurred in the first or the second clause of a two-clause sentence. The clause manipulation was chosen because information in the second clause of a sentence has been shown to be more available than information in the first clause of a sentence (Caplan, 1972; Chang, 1980). According to Bever and Hurtig (1975), this is because information within a clause is actively maintained in a relatively verbatim form until the clause boundary at which point it is recoded into a higher-level representation. If speech-based codes are used to maintain the verbatim representation of words within a clause, rhyme priming might be expected to vary as a function of clause structure.

METHOD

Subjects

Forty-eight Wayne State University students participated in order to satisfy a course requirement.

Materials

The test materials were drawn from 32 sentence sets. Each set contained four two-clause sentences followed by a target word. The sentences either contained a prime word that rhymed with the target but was spelled differently (e.g., cream-theme) or a control prime that was similar in meaning to the rhyme prime (e.g., milk) but did not rhyme with the target. In half of the sets the prime word was in the second clause. Two versions of each sentence were constructed, one in which the sentence ended four words after the prime and one in which the sentence ended seven words after the prime. Sample materials are presented in Table I. The full set of materials are presented in the Appendix. The four sentences in each set were assigned to different lists. The design was a $2 \times 2 \times 2$ with the factors being Prime, Clause, and Distance. Clause was nested within sentence set, while Prime and Clause were crossed. All factors were crossed with subjects.

Table I. Sample Stimuli for the Experiment

Condition	Stimulus Sentences and Targets Sentence	Target
First Clause		
4 Intervening Words	Since Jane forgot to put in all the (cream, milk) the cake was dry.	Theme
7 Intervening Words	If the pitch was a (ball, strike) the other team would win the game.	Haul
Second Clause		
4 Intervening Words	Because the murderer left no clues, the (sleuth, cop) couldn't crack the case.	Booth
7 Intervening Words	The thief got away but the (purse, fur) was soon found in the back alley.	Verse

Procedures

There were forty-eight filler sentences in which the position of the prime word was varied. Twenty of these sentences were followed by a rhyming nonword target, twenty were followed by a nonrhyming nonword target, and eight were followed by nonrhyming word targets. The test sentences on each list were intermixed with filler sentences. The lists were recorded and a timing tone inaudible to the subject was placed on one channel of the tape coinciding with the end of the sentence. The tone was used to trigger display of the target using a Gerbrands projection tachistoscope. The target was rear-projected at a visual angle of approximately 1.2° vertical and 5.6° horizontal. The target was displayed 100 msec after the end of the sentence and subjects responded "yes" or "no" aloud depending on whether the target was a word or not. Responses were timed using a millisecond clock which began timing when the target was presented. On approximately 25 percent of the trials, subjects were asked true-false questions to ensure that they were comprehending the sentences.

Table II. Results by Condition in msec

	Target Type		Facilitation
	Rhyme	Nonrhyme	
First Clause			NR-R
4 Intervening words	696 (3%)	730 (2%)	+34
7 Intervening words	713 (1%)	717 (2%)	+4
Second Clause			
4 Intervening words	681 (3%)	702 (2%)	+21
7 Intervening words	696 (2%)	698 (2%)	+2

Note: Lexical decision times are in msec and error rates are in parentheses.

RESULTS AND DISCUSSION

Mean lexical decision latencies and error rates for each of eight prime conditions are presented in Table II. Facilitation scores for each condition were calculated by subtracting lexical decisions to the target in the rhyme condition from lexical decisions to the target in the nonrhyme condition. Facilitation obtained when there were four intervening words between the prime and the target but not when there were seven intervening words. The same pattern of results obtained regardless of whether the prime was in the first or the second clause.

The reaction time data were analyzed using separate ANOVAs treating subjects and materials as random factors. These analyses revealed a main effect of Clause in the subject analysis $F(1, 47) = 14.86, p < .01$ and in the item analysis $F(1, 30) = 1.74, p < .05$, indicating that second clause items were faster than first clause items. The other main effects were Rhyme in the subject analysis $F(1, 147) = 5.47, p < .05$, indicating that rhyming targets were faster than nonrhyming targets (696 msec vs. 712 msec). However, the effect of rhyme was not significant in the item analysis $F(1, 30) = 2.60, p > .05$. The main effect of Length in both the subject and item analysis was not significant $F < 1.0$. There was a significant Rhyme \times Length interaction in the subject analysis $F(1, 47) = 6.66, p < .05$ and in the item analysis $F(1, 30) = 4.64, p < .05$. None of the other interactions approached significance.

The results demonstrate that rhyme priming can be obtained in a cross-modal lexical decision task. In addition they provide some estimate of the availability of phonological codes for words. Rhyme priming obtained four but not seven words after the prime, suggesting that the phonological code for a word remains active for several seconds. However, the results do not provide clear evidence about the locus of the

rhyme priming effect. The most likely possibility is that the effect is a lexical one. On this account, rhyme priming obtains because phonologically similar words are activated when a word is processed and this activation decays fairly rapidly. An alternative possibility is that the phonological code for a word remains active as long as the word is being held in working memory. The duration of rhyme priming would then be contingent on how long the word was retained in working memory. The failure to find an effect of clause would seem to argue against this interpretation. However, as with most negative results there are alternative interpretations. It may be that words within clauses are not actively maintained in working memory or that if they are, phonological codes are not used to help maintain them. Further research is clearly necessary to distinguish among these possibilities.

If rhyme priming is purely a lexical phenomenon, then it will be of limited usefulness in investigating higher-order (post-lexical) processes in comprehension. Nonetheless, the fact that phonological codes for words remain active for at least four subsequent words may be important for comprehension. For example, the time course for the decay of phonological codes for words may set limits on the number of words that subjects can process as a chunk. From this perspective, it is interesting to note that two-stage parsers such as Frazier and Fodor (1978) assume that the initial phrase structure parse is limited to sequences of six words or less. Finally, the fact that phonological codes for words remain active for durations of several seconds may be important for recovering from local garden paths at both the structural and lexical level. For example, ambiguity resolution typically takes place within several hundred milliseconds (Onifer & Swinney, 1981; Swinney, 1979; Tanenhaus, Leiman, & Seidenberg, 1979; Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982). In cases where the wrong meaning is initially chosen, the availability of a phonological representation for the word, may allow the listener to rapidly recover the correct meaning.

Finally it is important to raise one issue of interpretation. Koriat (1981) and Seidenberg, Waters, Sanders, and Langer (1984) have recently demonstrated that lexical decision is subject to "backward-priming" effects in which the facilitation in making lexical decisions to a target is due to the target-prime relationship and not the prime-target relationship. Thus the present results may be due to backward priming. However, even if this is the case they still provide useful evidence about the time course of the availability of the prime. It will be important, however, to replicate the present results with the naming task, which does not appear to be sensitive to backward priming, Seidenberg et al. (1984).

APPENDIX

This Appendix lists the test sentences used in the experiment. The first word in parentheses is the rhyming prime and the second is the control prime. The target word is italicized.

First clause

1. a. When the boy slipped on the (soap, stairs), he broke his leg.
b. When the boy slipped on the (soap, stairs), and he broke both of his legs.
POPE
2. a. Although the puppy was (cute, sweet), Rich chose the cat.
b. Although the puppy was (cute, sweet), Rick chose the big fat alley cat.
ROOT
3. a. When Jane returned the (skirt, blouse), she bought a hat.
b. When Jane returned the (skirt, blouse), she bought a straw hat on sale.
HURT
4. a. Since the price is so high for (roast, beef), shoppers are buying chicken.
b. Since the price is so high for (roast, beef), shoppers are buying more chicken than ever.
GHOST
5. a. After the bride removed her (veil, ring), she began to blush.
b. After the bride removed her (veil, ring), her face began to turn deep red.
TALE
6. a. Although the shop contained many (toys, things), trains sold the fastest.
b. Although the shop contained many (toys, things), trains always sold the fastest at Christmas.
NOISE
7. a. Although the club members had taken a (vote, stand), the issue was unresolved.
b. Although the club members had taken a (vote, stand), the issue still remained far from resolved.
BOAT
8. a. Since he had heard the (joke, pun), it wasn't very funny.
b. Since he had heard the (joke, pun), it wasn't very funny to him now.
OAK

9. a. Although the muffler was (loose, noisy), Bill drove his Chevy.
b. Although the muffler was (loose, noisy), Bill continued to drive his old Chevy.
JUICE
10. a. After they made (birch, bark) canoes, the warriors attacked.
b. After they made (birch, bark) canoes, the warriors mounted a surprise attack.
SEARCH
11. a. There was a large turnover in (staff, workers) when profits dropped sharply.
b. There was a large turnover in (staff, workers), because the company had been financially unstable.
GRAPH
12. a. Even though Jack could not give up (tea, coffee), he didn't drink pop.
b. Even though Jack could not give up (tea, coffee), he decided not to drink any pop.
KEY
13. a. After the team (won, lost), the players went drinking.
b. After the tam (won, lost), the players went to the Irish bar.
GUN
14. a. Since the ocean had completely eroded the (beach, shore), many resort hotels closed.
b. Since the ocean had completely eroded the (beach, shore), many resort hotels were forced to close.
SPEECH
15. a. After the thief snatched the (purse, fur), he fled very quickly.
b. After the thief snatched the (purse, fur), he escaped by running down the alley.
VERSE
16. a. Although this terrible economic climate hasn't affected (some, rich) people, workers are poorer.
b. Although this terrible economic climate hasn't affected (some, rich) people, the working classes are hard hit.
DUMB

Second clause

17. a. The student got very upset when he (heard, thought) about the tuition raise.
b. The student got very upset when he (heard, thought) about the tuition raise the board passed.
BIRD

18. a. Bill couldn't remember the words to the song but the (tune, beat) was on his mind.
b. Bill couldn't remember the words to the song but the (tune, beat), had been on his mind for days.
MOON
19. a. Many people had left but the (game, party) went on for days.
b. Many people had left but the (game, party) went on for days before finally ending.
CLAIM
20. a. Because the murderer left no clues, the (sleuth, cop) couldn't crack the case.
b. Because the murderer left no clues, the (sleuth, cop) couldn't crack the case for several weeks.
BOOTH
21. a. Jane went back to the store because she needed (cream, milk) for the cake recipe.
b. Jane went back to the store because she needed (cream, milk) for the chocolate and walnut cake recipe.
THEME
22. a. The kids went to the zoo to see the animals and the baby (deer, bear) was the top attraction.
b. The kids went to the zoo where the old (deer, bear) does tricks for peanuts and candied popcorn.
STARE
23. a. Because it was perfectly symmetrical, the (jewel, ruby) cost millions of dollars.
b. The museum was eager to make the purchase because the (jewel, ruby) was perfect and worth millions of dollars.
RULE
24. a. After Sally got drunk last night, her (head, stomach) hurt for many days.
b. After Sally got drunk last night, her (head, stomach) hurt for most of the next day.
BED
25. a. Poetry has rich imagery but (prose, speech) has variety of rhythm.
b. Poetry has richer imagery but (prose, speech) has greater irregularity and variety of meaning.
TOES
26. a. The man became lonely, after his (mate, wife) left on a cruise.
b. The man became lonely, after his (mate, wife) left on a cruise around the world.
EIGHT

