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### Loci of Contextual Effects on Visual Word-Recognition

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Some results and implications are summarized from reaction-time experiments in which subjects either (a) classified successive strings of letters as words and nonwords, or (b) pronounced the strings. Both types of response to words (e.g., BUTTER) were consistently faster when preceded by associated words (e.g., BREAD) rather than unassociated words (e.g., NURSE). A larger association effect occurred for visually degraded words than for words displayed intact. Reaction time was also affected by the phonemic relation between words. These results together suggest that semantic context may influence an early stage of visual word-recognition in which strings of letters are encoded graphemically and transformed to phonemic representations used for accessing lexical memory. Other possible explanations are also considered.

### I. Introduction: The Role of Semantic Context in Word-Recognition

Among man's most remarkable skills is the speed with which he can recognize spoken and written words. Although an educated person has thousands of words to discriminate in his vocabulary, he is able to process hundreds of them per minute (Pierce and Karlin, 1957). This ability may depend at least partly on semantic context, and so it is especially important to understand how people use contextual information. In an effort to solve the problem, we have devised a variety of reaction time (RT) procedures (Meyer and Schvaneveldt, 1971; Meyer, Schvaneveldt and Ruddy, 1972, 1974; Ruddy, Meyer and Schvaneveldt, 1973;

Schvaneveldt and Meyer, 1973). The goals of our research are to determine what operations mediate the process of word recognition and how semantic context influences it. The purpose of the present paper is to summarize some recent results concerning these questions.

#### A. BASIC PROCEDURE: THE LEXICAL-DECISION TASK

Our basic procedure involves measuring how quickly people can classify various strings of letters as English words or nonwords (Landauer and Freedman, 1968; Meyer and Ellis, 1970; Rubenstein, Lewis and Rubenstein, 1971; Snodgrass and Jarvella, 1972; Stanners and Forbach, 1973). Table 1 illustrates some examples of the stimuli used in this

TABLE 1. Examples of stimulus pairs in the lexical-decision task.

Stimulus Type	Examples	Correct Responses	Relative Frequency
associated words	BREAD-BUTTER NURSE-DOCTOR	yes-yes	0.222
unassociated words	BREAD-BUTTER BREAD-DOCTOR	yes-yes	0.222
word-nonword	WINE-PLAME HAIR-VEATH	yes-no	0.222
nonword-word	SOAM-GLOVE	no-yes	0.222
nonword-nonword	NART-TRIEF FOCK-BAME	no-no	0.111

*lexical-decision task.* The stimuli include strings of letters grouped into pairs. Within a pair, either string may be a word or nonword. There are two types of word pairs. In the first type, the words are semantic associates like BREAD-BUTTER and NURSE-DOCTOR, selected from standard association norms (e.g., Bousfield, Cohen, Whitmarsh and Kincaid, 1961; Palermo and Jenkins, 1964). In the second type, the pairs consist of relatively unassociated words like NURSE-BUTTER and BREAD-DOCTOR, constructed by randomly interchanging members of the associated pairs. The other stimuli, such as WINE-PLAME, SOAM-GLOVE, and NART-TRIEF, have at least one nonword as either the first or second member. Each of these nonwords is pronounceable and looks similar to English, but is not a member of the language ("Webster's New Collegiate Dictionary", 1961).

Figure 1 outlines one version of our procedure employing such stimuli (Meyer *et al.*, 1972, 1974). The procedure includes a series of trials. Each trial begins with two central fixation points, one above the other, which serve as a warning signal during the foreperiod. Next the top point

is replaced by the first string of letters (e.g., NURSE) in one of the pairs, and the subject (*S*) must judge whether or not it is a word. He makes an answer (e.g., "yes") by pressing one of two finger keys. As soon as the *S* responds, the first string of letters is removed, and there is a short delay followed by the second string of letters (e.g., BUTTER) in the pair. The

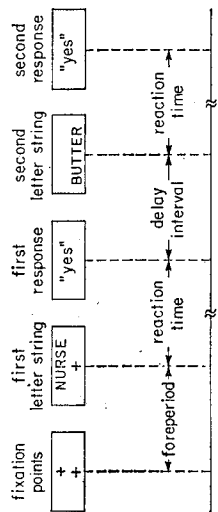


Fig. 1 Example of the basic procedure on each trial in the lexical-decision task.

*S* must then judge whether it is a word, and his answer (e.g., "yes") is again made by pressing one of two keys. Reaction time is measured separately for each string from the stimulus onset to the keypress. After each trial, the *S* receives feedback about his performance. He is instructed to respond as quickly and accurately as possible. (For further methodological details, see Section II. A.)

#### B. EFFECTS OF SEMANTIC CONTEXT ON WORD RECOGNITION

Working with this procedure, we have been interested mainly in performance on the words rather than nonwords<sup>1</sup>. In particular, the procedure provides information about how recognition of the second word in a pair depends on the context established by the first word. Some findings about this matter are summarized in Fig. 2. Here we have plotted results for positive responses to the second word of a pair when it was either associated or unassociated with the first word. The connected points indicate the mean RTs of correct responses plus-or-minus one standard deviation measured by the vertical axis on the left. The bars underneath give the error rates measured by the vertical axis on the right. As the figure shows, RT is shorter and there are fewer errors for associated than unassociated words. This is a good example of the way semantic context can facilitate word recognition. The difference in RTs for the two kinds of stimuli is reliable across both the individual words and *S*s. Since there is a corresponding difference in error rates, the variation in RT is probably not caused by a speed-accuracy tradeoff.

<sup>1</sup> Results from nonwords will therefore be omitted. However, some data concerning such stimuli can be found elsewhere (e.g., Meyer and Schvaneveldt, 1971; Meyer, Schvaneveldt and Ruddy, 1974; Schvaneveldt and Meyer, 1973).

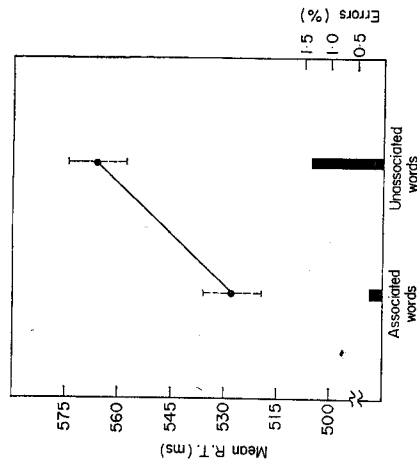


Fig. 2 Effects of semantic context on positive responses to the second member of associated and unassociated word pairs in the lexical-decision task.

#### C. INTERPRETATION OF THE SEMANTIC-CONTEXT EFFECT

What mental operations are being influenced by semantic context? One possible answer is in terms of the general theoretical framework outlined in Fig. 3 (Rubenstein *et al.*, 1971; Sternberg, 1969). Here the process of visual word-recognition has been divided into three separate stages connected by horizontal arrows. According to this view, the first

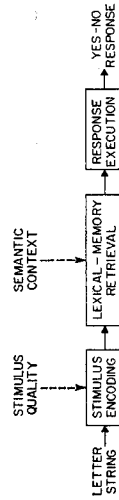


Fig. 3 Possible stages of word recognition. Horizontal arrows show the presumed sequence of operations, while vertical arrows indicate hypothesized effects of semantic context and stimulus quality on these processes.

stage involves an encoding operation that creates an internal stimulus representation, which might be graphemic, phonemic, or some other form. After encoding, lexical memory is accessed to determine whether the stimulus representation has been stored there previously<sup>2</sup>. Depending on the outcome of the retrieval process, a positive or negative response is then executed in the third stage. For example, if the stimulus representation is found to match some entry in memory, then the *S* would respond

<sup>2</sup> For purposes of the present discussion, we shall not be concerned about the precise nature of the retrieval process. It might involve a parallel or serial search such as Sternberg (1969) has considered for short-term memory, although the rate of search could be considerably greater in long-term (lexical) memory (Landauer and Meyer, 1972). Alternatively, the retrieval process may permit direct access to the information being sought (Meyer and Ellis, 1970).

'yes' it is a word. But if a match is not found, then he would respond 'no'. Such a series of operations is analogous to the way a person might use an ordinary dictionary to decide whether or not a string of letters is a word. The total RT would be the sum of the times taken by the three stages, as symbolized in Eqn. 1:

$$RT = T_1 + T_2 + T_3. \quad (1)$$

During this sequence of operations, semantic context might conceivably influence any of the three stages. However, in a paper presented at the Fourth Attention and Performance Symposium, we argued that the response stage is not affected (Schvaneveldt and Meyer, 1973). Instead, we suggested a *spreading-excitation model* that might function during the retrieval process, producing a contextual effect as shown by the right vertical arrow in Fig. 3.

The model includes two basic assumptions similar to ones that other investigators have adopted (e.g., Collins and Quillian, 1970; Loftus, 1973; Meyer, 1970, 1973; Morton, 1969; Norman, 1968; Rumelhart, Lindsay and Norman, 1972; Warren, 1972). The first assumption is that words are stored at distinct 'locations' in lexical memory and the memory is organized semantically, so that in some sense, associated words like BREAD and BUTTER are relatively close together whereas unassociated words like NURSE and BUTTER are farther apart<sup>3</sup>. The second assumption is that accessing information from a given memory location produces residual neural activity that spreads to other nearby locations. This temporary increase of excitation then produces the faster recognition of associated words. Such a contextual effect would occur, for example, if a person first searches for a stimulus representation in the memory locations of stored words that have been activated by preceding items.

Several of our findings support the spreading-excitation model. For example, the contextual effect decreases as the delay interval increases between the two words (Meyer *et al.*, 1972). That is exactly what should happen if the excitation decays over time.

## II. Experiment 1: Interaction of Semantic Context and Stimulus Quality

Now let us consider some further work concerning the nature of recognition processes and their dependence on semantic context. We will describe three studies testing our hypothesis that the contextual effect occurs during a retrieval operation after stimulus encoding. Although the

<sup>3</sup> Of course, we do not mean to imply that different words are necessarily represented at separate physical points in the brain. The spatial model is merely intended to provide a useful analogy.

hypothesis seems logically plausible, the data suggest that it may be incorrect, and that semantic context may influence encoding instead.

To reach this conclusion, we began by modifying a technique developed by Sternberg (1969). In the experiment, Ss had to classify successive strings of letters as words or nonwords. The procedure was similar to the lexical-decision task outlined in Fig. 1. However, besides manipulating associations within pairs of words, we also varied the stimulus quality (see Meyer *et al.*, 1972). On some trials, both words of a pair were displayed *intact*, such as the one in Fig. 4(a). On other trials, the first word of a pair was clearly visible, but the second word was visually degraded by superimposing a grid of dots over it as shown in Fig. 4(b). The masking pattern reduced discriminability but did not obscure the letters excessively, so that RT increased without a marked increase in errors.



FIG. 4(a) Example of a word displayed intact in Experiment 1.

This provided a way of making inferences about the locus of the contextual effect. Based on Sternberg's research, we hypothesized that stimulus quality would influence only the initial encoding operation, as shown by the left vertical arrow in Fig. 3. Hence, if semantic context only influences the subsequent retrieval process in lexical memory, its effect should be independent of stimulus quality. One would therefore expect additive effects of stimulus quality and semantic context on RT, since the duration of the first stage would depend on the former factor, while the duration of the second stage would depend on the latter factor but not the former (Sternberg, 1969). On the other hand, if semantic context and stimulus quality both influence the same stage, then they would probably interact in some way.

## A. METHOD

The experiment was controlled by a digital computer connected to a random-noise generator, display oscilloscope (CRT), and response panel with finger keys for the right and left hands. Eight high school students and eight employees of Bell Laboratories served as paid Ss who were run individually.

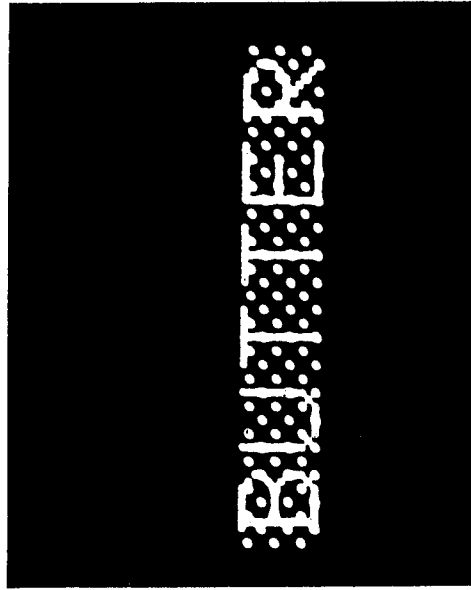


FIG. 4(b) Example of a degraded word in Experiment 1.

The S sat in a darkened room facing the CRT and wearing a pair of headphones. He participated in a single 1 h session that included a short instruction period, two practice blocks of 27 trials each, and eight test blocks of 27 trials. At the start of a trial, the S heard a soft burst of white noise that remained on throughout the trial and helped to mask extraneous sounds. Five hundred ms after the noise began, two central fixation points appeared one above the other on the CRT during a 500 ms foreperiod that ended with presentation of the first letter string in a pair. The S pressed a "yes" key with his left index finger to indicate the string was a word, otherwise pressing a "no" key with the left middle finger to indicate it was a nonword. Immediately following the response, the first string of letters was removed, and the second string was shown directly below it without any delay. The S again had to judge whether or not the string was a word. Another set of keys was used for this response. He pressed a "yes" key with the right index finger or a "no" key with the right middle finger to indicate his decision, thereby removing the stimulus.

The two strings were displayed in capital letters. Each string subtended approximate horizontal and vertical visual angles of 3° and 0.4°, respectively, and the fixation points were separated vertically by about 0.7°. On

half of the trials, the second string was degraded by the masking grid of dots. Reaction time for each string was recorded to the nearest ms. After the response to the second string, the CRT remained blank for about 2 s before the next trial. If the S made an error, this interval was extended to 4 s, during which the word INCORRECT was displayed for the first two seconds.

When the trial block was finished, the S received feedback about his mean RT, total number of correct responses, and total number of errors for the block. There was a rest period of approximately 2 m between blocks. The high school students were paid \$1.25 for participating in the experiment. In addition, both these and the other Ss were given a bonus for responding quickly and accurately. They earned 1 cent for each correct trial, lost 2 cents for each trial on which an error occurred, and also lost 2 cents for each 0.1 s in their mean RT on every block.

During the two blocks of practice trials, each S classified 24 word-word (WW) pairs, 12 word-nonword (WN) pairs, 12 nonword-word (NW) pairs, and 6 nonword-nonword (NN) pairs. None of the practice stimuli was seen again later in the experiment, and no explicitly associated words were included among them. On the subsequent eight blocks of test trials, each S was presented 48 associated WW pairs, 48 unassociated WW pairs, 48 WN pairs, 48 NW pairs, and 24 NN pairs. For examples of these, see Table 1.

The test stimuli were drawn from the following pool of items: 96 associated WW pairs; 96 unassociated WW pairs obtained by randomly interchanging first members of the associated pairs; 96 WN pairs; 96 NW pairs obtained by reversing the WN pairs; and 48 NN pairs, of which 24 were reversals of the other 24. The strings of letters were similar to stimuli described elsewhere (Meyer and Schvaneveldt, 1971; Schvaneveldt and Meyer, 1973) in terms of length, frequency (Kučera and Francis, 1967), and other properties.

An incomplete-block design was used for assigning stimuli to the Ss. Over the eight test blocks, each S saw half of the pairs of each type listed above. The stimulus assignment was balanced across Ss so that no one judged the same string of letters more than once. Each string appeared equally often intact or degraded. For example, each associated WW pair was presented to eight Ss, four of whom saw the second word intact; the corresponding unassociated WW pairs were presented to the remaining eight Ss, four of whom also saw the second word intact. Similarly, each WN, NW, and NN pair was assigned to eight Ss, four of whom saw the second string intact. If an S had to classify particular WN, NW, and NN pairs, then he was not presented the pairs obtained by reversing them. During each test block, the stimuli were displayed with the relative frequencies indicated by Table 1. Thus, approximately 67% of the letter strings were words. The order of presenting the pairs was random within blocks.

### B. RESULTS

The data were submitted to an analysis of variance similar to the one described by Meyer *et al.* (1974). In this analysis, both the stimuli and Ss were treated as "random effects", so that standard deviations and *F*-ratios reported below indicate the reliability of the results over both of these sampling domains<sup>4</sup>.

Table 2 outlines some of our results for pairs of words, which are of principal interest. Here we have summarized both the mean RTs of

TABLE 2. Mean RT of correct responses and percentage of errors for the second member of word pairs in Experiment 1.

Stimulus Quality	Semantic Context	Mean RT (ms)	Mean % Errors
intact	associated	528	0.3
	unassociated	566	1.3
degraded	associated	657	1.9
	unassociated	728	3.4

correct responses and percentage of errors for the second word in associated and unassociated pairs. Data from the intact and degraded stimuli are shown separately<sup>5</sup>.

There were substantial main effects of semantic context and stimulus quality on RT. Responses were  $55 \pm 7$  ms faster on the average for associated than unassociated words;  $F(1, 4) = 27.1, p < 0.01$ . The degraded words took  $146 \pm 12$  ms longer than the intact words;  $F(1, 4) = 98.9, p < 0.001$ . There was also a reliable interaction between the effects of semantic context and stimulus quality;  $F(1, 14) = 5.2, p < 0.05$ . The contextual effect was  $33 \pm 8$  ms larger for degraded than intact words.

A similar pattern of results occurred in the error rates. The stimulus quality and contextual effects were both significant at the 0.10 level;  $F(1, 14) = 4.5$ , and  $F(1, 13) = 3.2$ , respectively. Although the effects of these two factors on error rates did not interact reliably ( $F < 1.0$ ), the contextual effect was larger for degraded than intact words.

### C. DISCUSSION

Since the difference between RTs for associated and unassociated words depended strongly on whether they were intact or degraded, one must

<sup>4</sup> Standard deviations, *F*-ratios, and degrees of freedom were derived from combinations of the main effects and interactions of the treatments, stimuli, and Ss. The degrees of freedom differ from one test to the next because they depend on values of the mean squares involved. For a description of the computation, see Winer (1962, pp. 199-207) and Meyer *et al.* (1974).

<sup>5</sup> To shorten the exposition, we have omitted data from responses to first members of the various pairs. Results for those items may be obtained from us upon request.

reject the original additivity hypothesis. It appears instead that semantic context and stimulus quality influence a common stage. The observed interaction between these factors could be explained in several ways. For example, within the framework of the model in Fig. 3, both semantic context and stimulus quality might influence encoding, contrary to our original hypothesis. On the other hand, it is also conceivable that the two factors both influence the subsequent retrieval process. Thus, additional work is needed to test these alternatives and to learn more about the operations involved. In the following studies, we develop one theoretical account, but also shall mention other possibilities to be considered in future research.

### III. Experiment 2: Effects of Graphemic and Phonemic Relations on Visual Word-Recognition

The second experiment provided information about what kind of stimulus representation is used in recognizing a printed word. On each trial in this study, Ss again had to judge whether two successive strings of letters were words or nonwords. However, instead of manipulating stimulus quality and semantic context within the pairs of words, we examined the effects of graphemic and phonemic relations on recognition.

#### A. METHOD

The left half of Table 3 shows some examples of the stimuli involved. In the top panel are pairs of rhyming words (Type A) such as BRIBE-TRIBE and FENCE-HENCE, which differ only in their initial letter and

TABLE 3. Stimuli and results from Experiment 2.

Stimulus Type	Graphemic Relation	Phonemic Relation	Examples	Mean RT (ms)	Mean % Errors
A	similar	similar	BRIBE-TRIBE FENCE-HENCE	589	1.4
B	dissimilar	dissimilar	BRIBE-HENCE FENCE-TRIBE	605	0.8
C	similar	dissimilar	COUCH-TOUCH FREAK-BREAK	633	3.9
D	dissimilar	dissimilar	COUCH-BREAK FREAK-TOUCH	599	2.8

are therefore both graphemically and phonemically similar. In the second panel are corresponding control pairs of dissimilar words (Type B) such as BRIBE-HENCE and FENCE-TRIBE, obtained by randomly interchanging members of the rhyming pairs. The third panel contains pairs

of words (Type C) such as COUCH-TOUCH and FREAK-BREAK, which are graphemically similar but phonemically dissimilar because they do not rhyme. Finally there are also dissimilar pairs (Type D) like COUCH-BREAK and FREAK-TOUCH, which provide controls for the corresponding pairs of Type C.

The procedure was similar to the lexical-decision task outlined in Fig. 1. All of the items were displayed intact. For a more complete description of the study, see Meyer *et al.* (1974, Exp. 2) and Ruddy *et al.* (1973).

#### B. RESULTS

Using these stimuli, we were concerned with how recognition of the second word in a pair would be affected by its graphemic and phonemic relation to the first word. An answer may be found in the right half of Table 3, which gives the mean RTs of correct responses and percentage of errors for the second word in the various stimulus types.

The most important aspect of our results is that RT depended on the phonemic as well as graphemic relation between words. Recognition was inhibited when the stimuli were graphemically similar and phonemically dissimilar to each other, since words of Type C were classified more slowly than Type D. In contrast, phonemic together with graphemic similarity facilitated recognition, since words of Type A were classified somewhat faster than Type B.

Letting  $RT_I$  represent the mean reaction time for words of Type I, one may summarize this effect of phonemic similarity as follows:

$$RT_A - RT_B < RT_C - RT_D. \quad (2)$$

Statistical analysis reveals that the left term of the inequality is  $50 \pm 7$  ms less than the right term;  $F(1, 16) = 11.4, p < 0.01$ . None of the differences between the error rates approached reliability.

#### C. DISCUSSION

We shall not attempt to interpret these data fully here, since a complete account has been given elsewhere (Meyer *et al.*, 1974; Ruddy *et al.*, 1973). For present purposes, however, the experiment does have an important implication about encoding. If the words were always recognized directly from a graphemic representation, then performance could have been affected by the graphemic relation within stimulus pairs, but it should not have been affected by the phonemic relation. Instead, we found that the phonemic relation was quite important. This suggests that visual word-recognition relies on a phonemic representation of the stimulus at some point, and it appears that the initial encoding stage may include a grapheme-to-phoneme transformation by rule. An analysis of

data from nonwords used in the study also supports the argument (Meyer *et al.*, 1974)<sup>6</sup>.

As a result, Exp. 2 helps to resolve the question raised earlier about whether semantic context and stimulus quality both influence encoding or a later retrieval process in lexical memory. It is plausible to assume that a phonemic transformation during encoding would minimize effects of visual degradation on subsequent stages. Stimulus quality could therefore influence the encoding operation, but it would not substantially affect further processing. Consequently, one might infer that semantic context influences encoding too, since the contextual effect interacts with stimulus quality (Exp. 1).

#### IV. Experiment 3: Comparison of Performance in Lexical-Decision and Pronunciation Tasks

Such a conclusion may be evaluated against the findings of a third study. In this experiment, data from the lexical-decision task were compared with performance on a *pronunciation task* in which Ss vocalized strings of letters, rather than classifying them as words or nonwords. The main points of interest were the relative sizes of the semantic-context and stimulus-quality effects in the two tasks. To the extent that these factors produce similar results across tasks, this is consistent with the revised hypothesis that both effects occur during encoding.

#### A. METHOD

The study was controlled by the same equipment used previously, together with a microphone and voice key. Stimuli involving paired strings of letters were constructed and displayed intact or degraded as in Exp. 1 (see Table 1 and Section II.A.). Thirty-two high school students served as paid Ss who were run individually. Each S participated for two 1 h sessions on successive days. The first session included a short instruction period followed by five blocks of 27 practice trials each, which familiarized the Ss with the apparatus. One warm-up block and eight test blocks of 27 trials were then completed during the second session.

We divided the 32 Ss randomly into test and control groups of 16 each. In the control group, Ss performed a lexical-decision task similar to Exp. 1 (see Fig. 1). Every trial of the task began with two fixation points, followed by the first string of letters in one of the stimulus pairs. The S decided whether or not it was a word, pressing a key with his right index finger to indicate a "yes" decision, or another key with the left

<sup>6</sup> Although alternative interpretations of their results are possible, a similar conclusion has been reached by Rubenstein *et al.*, who observed effects of pronounceability and homophony on visual word-recognition.

index finger for a "no" decision. This removed the first string, and there was a delay of 250 ms followed by the second string of letters. The *S* again had to judge whether it was a word, but rather than pressing a key to make the decision, he said either "yes" or "no" aloud instead. A vocal response was used so that the lexical-decision task would be more comparable to the pronunciation task described below. Reaction time for the second string was measured from stimulus onset to activation of the voice key. Feedback followed each trial as in Experiment 1.

The other group of *Ss* participated in the pronunciation task. During the first part of each trial, the sequence of events was exactly the same as in the lexical-decision task. In particular, the *S* had to judge whether or not the first string of letters in each stimulus pair was a word, pressing one of two finger keys to indicate his decision. However, his response differed for the second string. Regardless of whether it was a word or nonword, the *S* merely had to pronounce the string. For example, if the string was B-U-T-T-E-R, then the *S* said BUTTER. Reaction time was again measured from stimulus onset to activation of the voice key, after which the *S* received feedback about his performance.

We adopted a liberal criterion for scoring the accuracy of vocal responses in the pronunciation task. For both words and nonwords, the *S* only had to make his response consistent with the grapheme-phoneme correspondence rules of English. He did not necessarily have to give the commonly accepted pronunciation of a word. For example, if he saw a string of letters like P-I-N-T, then he was permitted to say it with a short vowel, even though the word PINT is usually spoken with a long vowel. This scoring system had a special purpose. It allowed the *S* to make his vocal response without logically needing to access lexical memory to determine whether the phonemic representation of the stimulus matched some item stored there. Instead, the *S* only had to perform a phonemic transformation by rule during the initial encoding stage. Subjects were encouraged to give the first pronunciation that came to mind, responding as quickly as possible.

From other standpoints, the design of the pronunciation task was similar to the lexical-decision task and followed the general structure of Experiment 1. As in that first study, *Ss* were rewarded according to a point system for fast and accurate performance.

## B. RESULTS

Our principal findings concern the effects of semantic context and stimulus quality on vocal responses to the second string in pairs of words. Data were submitted to an analysis of variance similar to the one used in Experiment 1.

Mean RTs of correct vocal responses to the second word in associated and unassociated pairs are shown in Fig. 5 as a function of stimulus quality

for the pronunciation and lexical-decision tasks<sup>7</sup>. Both tasks revealed significant effects of semantic context. The difference between RTs for associated and unassociated words averaged  $48 \pm 6$  ms;  $F(1, 8) = 44.0$ ,  $p < 0.001$ . Similarly, responses averaged  $112 \pm 8$  ms faster for intact than degraded words;  $F(1, 5) = 161.2$ ,  $p < 0.001$ . As in Exp. 1, the contextual effect was larger ( $28 \pm 7$  ms) for the degraded words;  $F(1, 12) = 7.6$ ,  $p < 0.05$ . This interaction is best seen by comparing the lengths of the dashed braces in Fig. 5, which indicate the differences in RTs for associated and unassociated words in the various conditions.

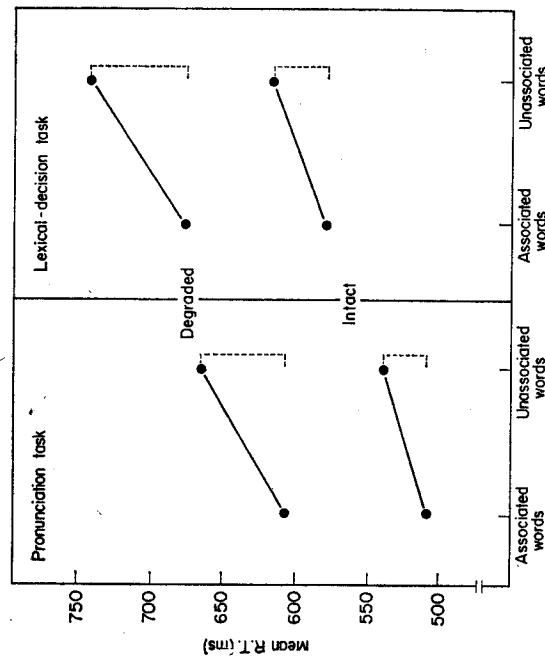


Fig. 5 Mean RTs of correct responses to the second member of word pairs in the pronunciation and lexical-decision tasks of Experiment 3. Data are shown separately for associated and unassociated words as a function of stimulus quality.

The only substantial difference between results from the two tasks was the overall speed of performance. Responses to the words averaged  $74 \pm 3$  ms faster in the pronunciation than lexical-decision task;  $F(1, 14) = 187.8$ ,  $p < 0.001$ . None of the higher-order interactions involving the tasks approached significance;  $F < 1.0$  in every case. The semantic context-by-task interaction was  $7 \pm 8$  ms; the stimulus quality-by-task interaction was  $1 \pm 11$  ms; and the triple interaction between these factors was  $2 \pm 10$  ms.

<sup>7</sup> Error rates in the two tasks were relatively low, averaging less than 5% and involving a pattern of effects similar to the RTs.

### C. DISCUSSION

Data from *Ss*' pronunciations demonstrate that effects of semantic context and stimulus quality are not limited to the classification of letter strings as words or nonwords, thereby supporting the generality of these results<sup>8</sup>. Based on the findings of Exp. 2, one may assume that the lexical-decision task includes an encoding operation that converts a string of letters to a phonemic representation, followed by a retrieval process in lexical memory and a yes-no response. On the other hand, the pronunciation task of Exp. 3 was designed to require a grapheme-to-phoneme encoding operation and not to necessitate subsequent retrieval from lexical memory or a yes-no response. It is therefore plausible to argue that the two tasks share a common stage, i.e., grapheme-to-phoneme encoding, but that they differ in terms of other processes involved. Consequently, the comparable effects of semantic context and stimulus quality across the tasks further indicate that these factors may both influence encoding. If the effects had occurred during some other stage, then the tasks might not have produced similar results.

### V. Conclusion: Toward a Theory of Visual Word-Recognition

To summarize our findings, one of the possible interpretations of the results from Exps. 1-3 is outlined in Figs 6(a) and 6(b).

#### A. MODIFIED STAGE MODELS FOR THE LEXICAL-DECISION AND PRONUNCIATION TASKS

In Fig. 6(a), we have proposed a model for the lexical-decision task in which strings of letters are classified as words or nonwords. According to this view, the stimulus is graphemically encoded and transformed to a

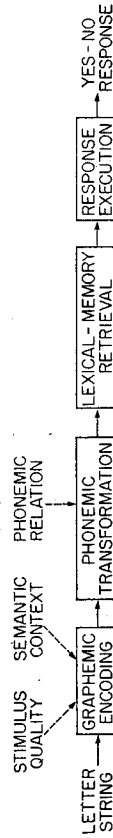


FIG. 6(a) Revised stage model for the lexical-decision task showing an influence of semantic context and stimulus quality on encoding.

phonemic representation through the grapheme-phoneme correspondence rules of English (see Rubenstein *et al.*, 1971). After encoding has been completed, lexical memory is accessed to determine whether the phonemic representation matches some item stored there. A yes-no response is

<sup>8</sup> Contextual effects on RT in a pronunciation task have also been reported by Jacobson (1973). Unfortunately, his results do not permit strong inferences about which stages of processing were involved, since stimulus quality was not varied systematically, and *Ss* apparently had to give the exact dictionary pronunciation of each word included.

then based on the outcome of the retrieval process<sup>9</sup>. The model is a special case of the one presented in Fig. 3, but now it assumes that semantic context as well as stimulus quality influences the graphemic-encoding operation rather than subsequent retrieval from lexical memory. This accounts for the interaction between semantic context and stimulus

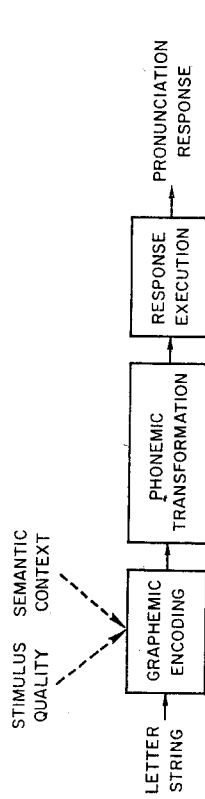


FIG. 6(b) Stage model for the pronunciation task obtained by modifying operations in the lexical-decision task.

quality observed in Exps. 1 and 3. The model further presumes that phonemic relations between words influence the phonemic transformation, thereby explaining the results of Experiment 2. A detailed mechanism that would produce the latter effect has been discussed by Meyer *et al.* (1974).

In Fig. 6(b) is a model for the pronunciation task. Performance here is assumed to involve graphemic encoding and a phonemic transformation, but not a later retrieval process for verifying whether the phonemic representation is stored in lexical memory. After a string of letters has been input and converted to a phonemic representation, it is simply output by the speech apparatus, yielding a pronunciation response. The phonemic transformation could be abbreviated because the output only has to obey the general grapheme-phoneme correspondence rules of English, and all possible representations of the stimulus do not have to be considered (see Meyer *et al.*, 1974). Again semantic context and stimulus quality are presumed to influence graphemic encoding. The model thus explains why the effects of these two factors were similar across the lexical-decision and pronunciation tasks in Experiment 3<sup>10</sup>. It is also consistent with

<sup>9</sup> Presumably encoding and retrieval would function as described by Meyer *et al.* (1974). As Rubenstein *et al.* (1971) have noted elsewhere, the retrieval process must include an ancillary operation for checking that a word is spelled correctly. This check could be performed after the phonemic representation of a letter string has been found to match some entry in lexical memory. Otherwise errors would occur on nonwords (e.g., BLOO) that are homophones of words (e.g., BLUE).

<sup>10</sup> Because of the way Exp. 3 was designed, no firm conclusions are possible about the effects of phonemic relations on transformations in the pronunciation task. Phonemic relations may be important only when a person compares the representation of a letter string with stored entries in lexical memory. This would be consistent with a mechanism that we have considered elsewhere to account for the results of Exp. 2 (Meyer *et al.*, 1974). Thus, to the extent that the pronunciation task does not require accessing lexical memory, phonemic relations may affect it less than the lexical-decision task.



our finding that responses to words were somewhat faster in the pronunciation task. This is exactly what one would predict if pronunciations include fewer operations than lexical decisions, as shown in Figs. 6(a) and 6(b)<sup>11</sup>.

Given the results of Exp. 3 alone, we have no need to presume that there is an effect of semantic context on lexical-memory retrieval beyond graphemic encoding. Our data suggest that contextual effects in other situations may also be limited primarily to encoding operations, contrary to the assumptions of various investigators (e.g., Collins and Quillian, 1970; Meyer, 1970; Rumelhart, Lindsay and Norman, 1972; Schaeffer and Wallace, 1970; Schvaneveldt and Meyer, 1973), who have presumed that differences in processing associated versus unassociated words occur mainly during retrieval and comparison stages after encoding. However, a few previous studies (e.g., Schaeffer and Wallace, 1969) have revealed larger differences between performance on associated and unassociated words than observed in Experiment 3. Thus, it is still possible that under some circumstances, other operations besides graphemic encoding are affected by semantic context.

How could semantic factors influence encoding before lexical memory is accessed? At least a partial answer might be based on the concept of spreading excitation discussed in Section I.C. Presumably there are structures in the brain that store information about whether a string of letters has been seen before. We have called these "lexical memory", and have assumed that the structures for associated words are adjacent in some sense, so that their memory locations are "close together". However, the neural signals that encode and transmit information about such words may share a common pathway even before they contact lexical memory. Spreading excitation could therefore increase the speed and sensitivity of visual-feature analyzers that form graphemic representations of associated words. This would explain why the effects of semantic context vary with stimulus quality even though the words are ultimately converted to a phonemic representation.

The preceding conjectures are testable in various ways. For example, one might try to vary stimulus quality, semantic context, and phonemic relations simultaneously in a lexical-decision task, since that was not done here. If effects of the first two factors are limited to graphemic encoding, while the latter factor influences a phonemic transformation, then stimulus

quality and semantic context should not interact with the phonemic relation.

#### B. ALTERNATIVE MODELS

Obviously, there are other ways to explain our results, and the stage models in Figs 6(a) and 6(b) may not be entirely valid. Despite the results of Exp. 2, some psychologists still might assert that words are at least sometimes recognized directly from their graphemic representations (e.g., Baron, 1973; Bower, 1970; Kollers, 1970)<sup>12</sup>. In that case, the encoding process would not necessarily involve a phonemic transformation, and semantic context could interact with stimulus quality during a subsequent retrieval stage. Even if a phonemic transformation always follows graphemic encoding, Exp. 3 may not have completely isolated the contextual effect during encoding. It is possible that the pronunciation task involved a phonemic representation initially obtained by rule to retrieve and check another one directly from lexical memory. Thus, except for the response stage, the pronunciation task may have included the same stages as the lexical-decision task, even though the instructions were designed to discourage this. It is also possible that encoding and lexical-memory retrieval occur as parallel dependent operations, rather than as separate stages. After a partial graphemic and/or phonemic representation of a word has been formed, retrieval governed by contextual information could interact with further encoding in a "constructive" fashion (Neisser, 1967).

#### C. SOME MODEL-FREE IMPLICATIONS

Regardless of what particular model is used to interpret our results, the present findings suggest some important points about the way words are recognized. To be specific, most previous studies concerning the effects of semantic context have focused on the accuracy of word recognition (e.g., Miller and Isard, 1963; Rubenstein and Pollack, 1963; Tulving and Gold, 1963; Tulving, Mandler and Bauml, 1964). In those experiments, there was usually a considerable interval separating the context and test words. While the words were difficult to perceive, Ss had a relatively long time to respond following the stimulus. Thus, the observed contextual effects might have happened after the words were encoded as much as possible. Based on partial information, Ss may have consciously tried to guess what stimulus had been presented.

However, our experiments indicate instead that the effects of context

<sup>11</sup> Alternatively, one could argue that the overall speed of performance in the two tasks differed because the response stages were not the same. For example, pronunciations may have been faster than lexical decisions because they are more highly practised responses to letter strings. However, this point should be weighed against the fact that response uncertainty was less in the lexical-decision than pronunciation task, since only two responses ("yes" or "no") were required there. Thus to the extent that Ss may prepare to execute a given response, one might have expected that the lexical decisions would actually be faster than pronunciations.

<sup>12</sup> The data do not rule out the possibility that printed words are recognized through both graphemic and phonemic representations. Indeed, retrieval processes based on the two types of code may be executed in parallel, so that recognition could occur when either the graphemic or phonemic representation of a word is found in lexical memory (Meyer *et al.*, 1974).

are rapid and automatic. Even when words are clearly visible and presented in immediate succession, RT is influenced by semantic context. Taking the results of Exps 1-3 together, one might therefore conclude that contextual effects occur quite early in the recognition process. Such a conclusion is consistent with the results of some other recent investigators (e.g., Jacobson, 1973; Reicher, 1969; Wheeler, 1970), and it extends the research that we reported at the last Attention and Performance Symposium (Schvaneveldt and Meyer, 1973).

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