Identification and pronunciation effects in a verbal reaction time task for words, pseudowords, and letters

PAUL G. ROSSMEISL

U. S. Army Research Institute for Social Sciences, Alexandria, Virginia 22333

and

JOHN THEIOS

University of Wisconsin, Madison, Wisconsin 53706

The question addressed in this investigation was whether faster reading and pronunciation of words than orthographically regular pseudowords is due to faster identification or to faster programming and execution of the motor response. In Experiment 1, three different response conditions (naming, three-choice signaled responding, and one-choice signaled responding) were employed to separate the identification and articulation processes in a verbal reaction time task. It was found that, for all intents and purposes, single, isolated letters are processed as if they were very short words. Words are read and pronounced 72 msec faster than pseudowords. Words are also pronounced 30 msec faster than pseudowords even if the reader has longer than 1 sec to identify the stimulus (three-choice condition) or to both identify the stimulus and preprogram the response (one-choice condition). The data indicate that words are identified about 52 msec faster and articulated about 30 msec faster than pseudowords. Since the number of response alternatives (one or three) does not interact with stimulus type (letter, word, or pseudoword) in the signaled response control condition, the 30-msec difference is due to response execution and not to differential response programming. Response programming takes in the neighborhood of 236 msec. Experiment 2 investigated the effect of local orthographic context upon the identification of the first letter of a string of letters. No difference was found in identifying the initial letter of words and pseudowords, but the initial letter of these orthographically regular letter strings was identified and named 10 msec faster than the initial letter of orthographically anomalous strings of letters (anagrams). The data from the two experiments are supportive of theories of reading that assume (1) that the letters of visually presented words are processed simultaneously, in parallel, (2) that there is a relatively direct access and retrieval of the phonological memory codes for the names of words, and (3) that orthographically regular pseudowords having no representation in the phonological lexicon undergo a grapheme-to-phoneme transformation that takes longer to finish than the direct spelling-to-sound process used for words.

The last few years have shown renewed experimental investigation into how words and letters are identified. Although many different techniques and paradigms have been employed in this investigation, one of the most popular has been the measurement and comparison of naming (reading-pronunciation) latencies from a verbal

reaction time (RT) task. The present study takes a closer look at what sort of psychological processes might produce differences in naming times and discusses the implications that such differences might have for an explanation of word and letter identification.

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In one of experimental psychology's earliest studies, Cattell (1886) used a reading-pronunciation task to study the identification of words and letters. Cattell observed that it took 22 msec longer to read and name a letter aloud than it did to read and name a short word. Since then, his finding has often been used to support a direct memory-access or whole-word processing theory of word recognition. However, such an interpretation of Cattell's results may not be warranted. In fact, Cattell attributed the word advantage to response factors rather than to stimulus identification. He noted that in spoken language words are pronounced much more frequently than letters, and that such frequency differences could result in the articulatory programming and execution

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times of letters being longer than the time needed to vocalize words.

Whether differences should be attributed to stimulus identification or response factors is a basic problem inherent in the reading-pronunciation task. The overall RT in such a paradigm can be expressed as $RT = t_I + t_R$, where the identification time (t_I) represents the time needed to reach a name code or a phonetic code for the stimulus (Posner, 1978; Theios & Muise, 1977). After an individual has a name for a stimulus, he must program an articulatory response based on the phonetic code and then execute that response. The time needed to perform these response operations is represented by t_R . Differences in overall RT can therefore result from either t_I or t_R .

Naming tasks have also been used to study the identification of words and pseudowords (Forster & Chambers, 1973; Frederiksen & Kroll, 1976). The problem under investigation in these studies concerned the manner in which a word is identified, given its visual representation. Theoretically, visually displayed words can be identified in two ways, according to these authors. The name of a word could be obtained by using grapheme-to-phoneme correspondence rules or by means of a direct dictionary (lexicon) lookup based upon visual information alone. On the other hand, pseudowords, which are novel stimuli, should not have a dictionary representation and, therefore, should only be named by implementing grapheme-to-phoneme processes. Given the Forster and Chambers and Frederiksen and Kroll reasoning, an experiment showing words being named faster than pseudowords would suggest that words can be identified more directly, without the use of grapheme-to-phoneme correspondence rules.

To test the possibility of direct identification of words, both Forster and Chambers (1973) and Frederiksen and Kroll (1976) compared the naming latencies of words and pseudowords. In both studies, the pseudowords were constructed by randomly changing one vowel of an English word (e.g., "clear" became "cloar"). It was assumed that such pseudowords were novel letter strings without a dictionary representation, but that they still followed the rules of English orthography. Using only 30 such word-pseudoword pairs, Forster and Chambers observed words to be named about 90 msec faster than pseudowords. The Frederiksen and Kroll experiment was more complicated than Forster and Chambers' study, since they chose to manipulate not only the lexical validity of the letter string but number of syllables in the letter string and blocked vs. mixed presentation as well. In their monosyllabic mixed-presentation condition (the condition that most closely resembled Forster and Chambers', 1973, study), they also observed a word advantage. In this case, with 240 stimuli of each type, words were named about 34 msec faster than pseudowords.

Such findings suggest that words are identified more directly without using grapheme-to-phoneme corre-

spondence rules. However, the studies of Forster and Chambers (1973) and Frederiksen and Kroll (1976) encounter the same difficulty in interpreting naming times as did Cattell's (1886) study comparing word and letter identification. When an observer reads and pronounces a pseudoword, he is forced to make an unfamiliar response. Therefore, differences in naming times between words and pseudowords could be the result of variations in response time as well as identification time.

The importance of response factors when comparing the naming times of words and pseudowords was demonstrated by a study conducted by Theios and Muise (1977). Theios and Muise attempted to control response factors as much as possible by constructing pseudowords that were homophonous with real words (e.g., "fame, faim," and "feel, feal"). With such tight response control, variation in naming times can be attributed to identification processes with more confidence, since response factors should be equal for the two types of stimuli for all intents and purposes. Using 100 matched stimulus pairs of this kind, Theios and Muise found words to be named only 20 msec faster than pseudowords. This difference is noticeably smaller than that obtained by Frederiksen and Kroll (34 msec) and considerably smaller than that of Forster and Chambers (90 msec). The reduced difference between words and pseudowords when response factors were controlled by Theios and Muise suggests that in the studies conducted by Forster and Chambers (1973) and Frederiksen and Kroll (1976), naming time was influenced by response factors as well as by the stimulus identification process.

In fact, Forster and Chambers (1973) recognized that variability in response times can render the results of a simple naming task ambiguous. Forster and Chambers attempted to account for response factors by including a naming control suggested by Eriksen, Pollack, and Montague (1970). In such a control, the observer is instructed to immediately identify a visually displayed stimulus but not to pronounce it until he is signaled to respond. The response timer would not be activated until the pronunciation signal was presented, and the resulting RT could be assumed to measure only response variation, since the observer should have identified the stimulus during the interval prior to the response signal. In their naming control, Forster and Chambers observed a nonsignificant 13-msec difference between pseudowords and high-frequency words. On the basis of this finding, they concluded that pseudowords and words do not differ in response time and that their finding of a 90-msec difference in simple naming time between the two stimulus types was attributable to differences in stimulus identification time.

Such a conclusion rests upon acceptance of the Eriksen et al. (1970) control for response time, and it is possible that this method, as used by Forster and Chambers (1973), may not be an accurate representation of all response variability. During the delay interval following the presentation of a single stimulus in the

control condition, the observer is not only able to identify the stimulus but can program its articulatory response as well, since he always knows what the correct response will be. This form of the Eriksen et al. control is therefore useful in investigating differences in response execution. But as the number of response alternatives increases, difference in response selection and programming time may develop, and these variations could increase the overall response difference among various types of stimuli. If one wishes to investigate response time thoroughly, it is necessary to manipulate the number of possible response alternatives and still control stimulus identification.

A second problem with the Forster and Chambers' (1973) study is that they used only 30 word-pseudoword pairs. With such a small number of stimuli, it is difficult to make general conclusions, since random factors involving particular stimuli will not be controlled.

Experiment 1 investigated the relationship between identification and response factors involved in verbal RT. Rather than directly controlling response time, as did Theios and Muise (1977), a modified Eriksen et al. (1970) procedure was employed so that response times could be investigated directly. The modification involved giving the observer more than one possible response alternative. This technique allowed the investigation of response selection and articulatory programming time, as well as response execution time. In particular, two questions were asked: Do various types of linguistic stimuli like words, pseudowords, and letters differ in overall naming times, and can similar differences be obtained when the observer pronounces a previously encoded and identified stimulus?

EXPERIMENT 1

Method

Procedure. Three response conditions were blocked into three experimental sessions. During the naming condition, observers were visually presented a random sequence of stimuli composed of words, pseudowords, and letters. The participants were instructed to simply read and pronounce each stimulus aloud. In the three-response-alternative condition, three stimuli were simultaneously presented and the observers were given sufficient time to encode and to identify all of them before an arrow indicated which of the three was to be pronounced out loud. During the single-response-alternative condition, a single stimulus was visually displayed, but, again, the observer was instructed not to respond until signaled by the appearance of an arrow. The order of these three conditions was counterbalanced across observers.

Each observer was seated in an Industrial Acoustics Company sound-attenuating room (Model 101696) and wore a Telex 1200 combination headphone-microphone headset. The microphone relayed the observer's vocalizations while -10-dB wide-band white noise from a Grason-Stadler 901B generator was presented over the headphones to further reduce auditory distractions. The stimuli were presented on a Tektronix Type RM 503 oscilloscope located 1 m directly in front of the observer. Whenever a stimulus was not being presented, a fixation point was displayed in the center of the circular oscilloscope field, which measured 11.5 cm in diameter. A Digital Equipment Corporation PDP-8

computer randomized the stimuli for each session and controlled stimulus presentation and response measurement and recording.

During the naming condition, each trial began with the presentation of a stimulus whose initial letter was located at the fixation point. The stimulus was continuously displayed until the observer made a verbal response, which activated a voice relay and terminated the stimulus presentation. The reading-pronunciation latency was then recorded, and the observer's vocal response was taped by a Sony TC129 cassette audio recorder. After a 2-sec delay, a new trial began and the procedure was repeated. Each word, pseudoword, and letter was tested once, and there were 336 stimuli of each type, for a total of 1,008 trials in the naming condition.

In the three-response-alternative condition, the fixation point was followed by three stimuli: a word, a pseudoword, and a letter. The three stimuli were always displayed simultaneously in a column centered in the middle of the visual field, but the position within the column of each stimulus type varied randomly from trial to trial. Each of the three stimuli displayed on any particular trial began with a different letter. The observers were instructed to identify and be prepared to pronounce each of the three stimuli. After a variable delay ranging from 1,150 to 1,250 msec, an indicator arrow appeared adjacent to and to the left of one of the three stimuli and the observer then pronounced the stimulus indicated by the arrow. After 250 msec, the next trial was initiated. Each word, pseudoword, and letter was tested once and served as a distractor twice, resulting in 1,008 total trials in this three-response-alternative condition.

The single-response-alternative condition was conducted in a manner similar to the three-choice condition, but only one stimulus was displayed per trial and it was always located in the middle position. The stimulus could be a word, pseudoword, or a letter. Again, the observers were instructed to identify the stimulus and be prepared to pronounce it, but to delay their response until the indicator arrow appeared. Each stimulus was tested once, again resulting in 1,008 trials.

Thus each experimental session consisted of 1,008 trials whose order was randomly determined for each observer by the computer. Each of the three sessions was divided into three blocks of 336 trials, and between each block of trials the observers were permitted a short rest period.

In all conditions, errors were excluded from the analysis. An error was defined as (1) a mistake in pronunciation, (2) the pronunciation of any stimulus other than the one indicated by the arrow, (3) a trial on which the RT exceeded 2,300 msec, or (4) a trial during which the observer initiated a response before the indicator arrow was actually displayed.

Stimuli. The words used were all common monosyllabic words ranging in length from three to five letters. They were selected so that each word was identical to two other words in the experiment in all letters save the first. The first letter of each word was therefore critical to the identification of the entire word. There were 24 words starting with each of 14 different initial consonants, for a total of 336 words.

Pseudowords were generated by changing one of the vowels of each word. The vowel switch was made so that the new stimulus would be pronounceable but not listed as an English word in *Webster's New College Dictionary* (1969).

All letters initiating words and pseudowords were presented individually during letter trials. The letters employed were b, c, d, f, g, h, i, l, m, n, p, r, s, t, and w, for a total of 14 different letters. In order to balance the experimental conditions, each letter was repeated 24 times, to obtain 336 letter trials.

Examples of 12 of the 336 words and 336 pseudowords used are presented in Table 1.

Observers. Eight female and four male observers participated in the study. They ranged in age from 18 to 24 years and were all native English speakers and undergraduates at the University of Wisconsin's main campus at Madison. All observers were volunteers and received course credit for their participation.

Table 1
Twelve Examples of the 336 of Each Type of Stimuli
Used in the Two Experiments

Words	Pseudowords	Letters	Anagrams
block	bleck	b	blcok
clock	cleck	c	clcok
flock	fluck	f	flcko
bark	berk	b	brka
mark	merk	m	mrka
park	purk	p	pkra
car	cor	c	cra
far	fer	f	fra
tar	tur	t	tra
craft	creft	c	cratf
draft	droft	d	dfrat
graft	grift	g	gtafr

Results

Error rates. Analysis of variance was conducted on the arcsin transformation of the error percentages. Statistical significance was not obtained for either the Stimulus Type by Response Condition interaction [$F(4,44) < 1$] or the main effect of stimulus type [$F(2,22) = 1.31, .50 < p < .75$]. The average error rates for the various stimuli were 1.60% for pseudowords, 1.40% for words, and 1.65% for letters. The error data from the three levels of response condition were significant [$F(2,22) = 19.54, p < .001$]. When there was one response alternative, the average error rate was 2.9%; an average of .9% of the three-response-alternative trials resulted in errors. During the naming condition, 1.1% was the average error rate. The greater number of errors in the single-response-alternative condition resulted primarily from an increase in anticipation responses. When there was only one alternative, the observers showed a slightly increased tendency (2%) to initiate their response before the arrow was displayed. In all conditions, the error rates were quite low and should not have greatly influenced the RT data. Given the overall error rate of 1.6%, an average of 331 trials contributed to each RT data point.

Reaction times. Considering the RT data, the main effects of stimulus type and response condition were found to be significant [$F(2,22) = 80.99$ and 23.83 , respectively; $p < .001$], as was the Stimulus by Response Condition interaction [$F(4,44) = 5.56, p < .005$].

The RTs from the naming condition, which was analogous to Cattell's (1886) study, are shown in Table 2. It is clear that words were not named faster than letters. In fact, the observed difference was in the opposite direction; letters were named 22 msec faster than words, although this difference was of marginal statistical significance [$F(1,44) = 4.88, .025 < p < .05$].

The 72-msec difference between pseudowords and words, however, was found to be significant [$F(1,44) = 52.23, p < .01$]. Whether such differences in reading-pronunciation latencies should be attributed to identification or response factors is still ambiguous. To illustrate this problem, consider the data from the conditions in

which identification time was not a component of the overall latencies. Examination of the pronunciation-only data control in Table 2 revealed an overall 236-msec difference in RT between the three- and one-choice conditions, but the set of six points are essentially parallel [$F(2,44) = .334$], indicating that in this case the relationships among the three stimulus types did not vary with the number of response alternatives.

Inspection of the stimulus type effect within these conditions showed that Cattell's (1886) initial hypothesis of a word advantage over letters was not supported. Under both response conditions, there was no significant difference between words (589 msec) and letters (579 msec) [$F(1,44) = 1.82$].

The 30-msec difference between pseudowords and words was significant [$F(1,44) = 18.16, p < .01$], however, suggesting that the response latency for these two stimulus types do indeed differ. This finding renders the previously mentioned difference in the naming times between the two types of stimuli somewhat difficult to interpret.

This difficulty is illustrated in Table 3, which shows the differences among the various stimulus types as a function of response condition. While the word-letter difference was fairly constant at about 14 msec [$F(1,44) = 1.05$], there was a significant jump from 30 to 72 msec in the difference between words and pseudowords in the naming condition [$F(1,44) = 11.85, p < .01$]. It is tempting to conclude that this jump is caused by a difference in identification time between words and pseudowords. This conclusion may not be warranted, however, since it assumes that the response difference between the two types of stimuli observed in the pronunciation-only conditions will not change when the observer simply names the stimulus. This assumption may not be valid, since the almost infinite response uncertainty in the naming condition might lead to larger response differences.

Table 2
Mean Correct Pronunciation Latencies (in Milliseconds),
Standard Error, and Error Rates (in Percentages) for
the Naming (Reading) Condition and the Two
Signaled-Response Control Conditions

	Stimuli			Error Rate
	Letters	Words	Pseudowords	
Reading				
Mean	585	607	679	1.1
SE	27	41	31	
One Choice				
Mean	464	472	503	2.9
SE	38	36	38	
Three Choices				
Mean	695	706	735	.9
SE	23	26	36	
Error Rate				
	1.1	1.4	1.6	1.6

Table 3
Response Latency Differences (in Milliseconds) for the
Three Different Response-Type Conditions

	Naming (Reading Pronunciation)	Controls	
		One-Choice Pronunciation	Three-Choice Pronunciation
		Word-Letter Difference	
Mean	22	8	11
SE	7	35	15
		Pseudoword-Word Difference	
Mean	72	31	29
SE	14	56	29

Discussion

Our observation of a small letter advantage over words in the naming condition is a failure exactly to replicate Cattell's (1886) earlier finding. This discrepancy may not be important, however, since it is difficult to assess the reliability of Cattell's results because he used only two subjects and a small number of stimuli, 13 of each class. Further, statistical methods to test hypotheses or establish confidence intervals were not available during his time. The small differences observed, therefore, might have resulted from random variation.

Since in the present study there was also no significant difference between words and letters in the pronunciation-only conditions, it is unlikely that the results of the naming condition can be attributed to conflicting identification and response processes. While small differences are difficult to interpret, it is still reasonable to conclude that single letters are identified slightly faster than multiletter words. This finding concurs with the earlier results and conclusions of a yes-no RT task conducted by Massaro and Klitzke (1977), but it is slightly at odds with an earlier yes-no study by Johnson (1977).

The comparison between words and pseudowords is not as clear as that between words and letters. Unlike the naming control of Forster and Chambers (1973), the results of the pronunciation conditions demonstrated that the two types of stimuli differ in articulatory response time. When such differences exist, naming time is not an unambiguous indicator of the time needed to identify a stimulus. Yet the finding of a significantly larger word-pseudoword difference when the stimulus is named rather than simply articulated merits further consideration.

One possible explanation for the larger difference in the naming condition is increased response uncertainty. As the number of possible response alternatives becomes very large, as in the naming condition, the difference observed in the two pronunciation conditions may become greater. Although this interpretation cannot be entirely ruled out, it seems to be an unlikely alternative, since the word-pseudoword difference did not vary when the number of response alternatives was increased from one to three.

A more likely explanation of this larger difference in the naming condition is that pseudowords take longer to identify than words. This interpretation is supported by the work of Theios and Muise (1977), which demonstrated a reliable 20-msec difference in naming time between words and pseudowords constructed to be homophonous with real words. With such stimuli, all response variables should be equal and any variation in naming times can be attributed to identification processes. Such an explanation is also in agreement with the earlier studies of Forster and Chambers (1973) and Frederiksen and Kroll (1976), who concluded that words can be identified without implementing the grapheme-to-phoneme correspondence rules needed to identify pseudowords.

Experiment 1 demonstrated the difficulty in interpreting differences in overall naming time when there is evidence suggesting response time differences. This problem can be avoided by using stimuli having the same articulatory response (homophones). If the responses are the same, the time needed to program and execute a response should be same for all stimuli. This was the technique employed in the study by Theios and Muise (1977), and a similar paradigm was used in Experiment 2 to study the effect of orthographic context upon letter identification.

EXPERIMENT 2

Reicher (1969) found tachistoscopic letter recognition to be significantly more accurate when the target letter was presented in a word than when the letter was part of a nonword that did not conform to the orthographic rules of English. This result was obtained despite a forced-choice procedure to control for the possibility of guessing during response selection. One interpretation of this finding is that observers are able to make use of orthographic information to aid the identification of individual letters when they are presented within an orthographically valid context (Massaro, 1973, 1975).

Orthographic context has also been shown to be an important variable in letter search tasks. Massaro, Venezky, and Tayler (1979) found that the time needed to search for a particular letter was faster if the letter was part of a word or an orthographically valid pseudoword than if the letter was embedded within an orthographically invalid nonword.

The purpose of Experiment 2 is to investigate the effects of orthographic context within a simple letter naming task using the response control methods suggested by Theios and Muise (1976). The observers were instructed to pronounce the first letter of a string of letters. The strings could be words, pronounceable pseudowords that follow the orthographic rules of English, or orthographically invalid anagrams. Since each of the test letters occurred in all three orthography conditions, articulatory response time should not have been a confounding factor in the overall RT.

Different theoretical versions of letter and word recognition models make contrasting predictions regarding the role of orthography in a naming task of this type. Recognition models proposing that the identification of the letters within a string proceeds in a left-to-right serial manner (Gough, 1972) should expect initial letter naming time to be unaffected by the orthographic properties of the subsequent letter string, since the first letter is identified before processing any of the other letters. Likewise, models of the type advocated by LaBerge and Samuels (1974) also should expect little influence of orthographic context upon the naming time of the string's initial letter. In LaBerge and Samuel's model, orthography is employed to process groups of letters automatically, that is without the use of focused attention. In such a system, individual letter identification is not aided by context; rather, valid orthography allows letter groups to be identified directly, automatically, or globally without previous identification of the component letters. If observers need attend and respond only to the initial letter of a stimulus, letter groups within that stimulus need not be processed at all, and orthographic information should not be utilized.

The model developed by Massaro (1975), however, does predict that orthographic context should exert a small but reliable influence upon the naming time of letters beginning letter strings differing in orthographic regularity. In the Massaro model, all of the letters of a word or nonword are identified simultaneously, in parallel. Furthermore, it is assumed that orthographic knowledge provides an independent source of information helping to identify each of the letters composing an orthographically valid letter string. In this case, the initial letter of orthographically regular strings should be identified faster and, thus, named faster than letters beginning orthographically invalid strings. This follows because the initial letter of an orthographically regular string will benefit from the additional contextual information provided by the processing of the orthographic properties of the string's other letters.

Method

The observers and apparatus were the same as those employed in Experiment 1. Half of the observers participated first in Experiment 1, and the other half began with Experiment 2.

Procedure. Each trial began with the visual presentation of a string of letters whose initial letter was located at what had been the fixation point. The stimulus was a word, a pseudoword, or an anagram, but the observer was instructed to name only the first letter of each string, regardless of its type. The observer's response activated a voice relay that terminated the stimulus presentation and recorded the response latency. The fixation point was then displayed for 2 sec before a new trial was initiated.

During the experiment, there was a total of 1,008 trials whose order was determined randomly for each observer by the computer. As in Experiment 1, the observers were allowed a short rest period between blocks of 336 trials.

All response errors were excluded from the analysis of the response latencies. An error was defined as either an incorrect pronunciation or the failure of an observer to respond within 2,300 msec.

Stimuli. The words and pseudowords used in Experiment 2 were the same as those employed in Experiment 1. Anagrams were constructed by scrambling all but the initial letter of the words. The resulting letter strings were highly unpronounceable and did not follow common English orthography. There were 336 stimuli of each type, examples of 12 of which are shown in Table 1.

Results

Analysis of the arcsin transformation of the error rates did not reach statistical significance [$F(2,22) = 3.6$, $p < .10$]. During the experiment, .8% of the pseudoword trials resulted in errors, and the error rates for words and anagrams were .4% and .6%, respectively. As in Experiment 1, the error rates were quite low and should not have influenced the RT data greatly.

The naming latencies for the first letter of the letter strings are shown in Table 4. The effect of letter-string type was found to be significant [$F(2,22) = 18.3$, $p < .01$]. Comparisons among the individual means revealed that naming the first letter of an anagram took significantly longer than naming the first letter of either a word [$F(1,22) = 36$, $p < .01$] or a pseudoword [$F(1,22) = 20.25$, $p < .01$]. The difference in naming times of the first letters of words and pseudowords was neither large (3 msec) nor statistically significant [$F(1,22) = 2.25$, $.10 < p < .20$].

Discussion

The lack of sizable difference in naming latencies between letters in words and letters in orthographically regular pseudowords suggests that the lexical validity of a letter string is not a factor in the identification of the first letter of that string. What is important in letter identification is the orthographic properties of the entire string, as evidenced by the increased naming times of letters initiating orthographically invalid anagrams.

One explanation of the word and pseudoword advantage is based on the observer's knowledge of English orthography. Massaro (1975) has developed a word and letter identification model in which letters are assumed to be identified in parallel and the identity of any particular letter is obtained not only by its own visual resolution, but through simultaneous contextual information provided by the resolution of its neighbors as well. Thus, according to this model, letters initiating orthographically valid strings should benefit from an orthographically regular context and should be named faster than letters initiating strings that are orthographically invalid, which is in fact the case.

Table 4
Mean Correct Pronunciation Latencies (in Milliseconds)
and Error Rates (in Percentages) for Initial Letters

	Letter Initiating		
	Words	Pseudowords	Anagrams
Mean	550	553	562
SE	20	18	18
Error Rate	.4	.8	.6

It is important to note that not all models proposing a facilitating effect of orthographic context can explain the findings of Experiment 2. As an example, in the model proposed by LaBerge and Samuels (1974), orthography is an important element, but it is assumed that orthographic context is employed only when the subject is processing at the letter level. In the LaBerge and Samuels model, orthography functions in reading by allowing the observer to process spelling patterns automatically without the use of focused attention. In our Experiment 2 task above, the observers were instructed to identify and name only the string's initial letter, not the entire string. According to the model advocated by LaBerge and Samuels, if attention is focused on an initial letter, orthographic context should not affect the identification time of that letter, since orthography is utilized not to identify individual letters, but to process patterns of letter strings automatically. Yet the first letter of an orthographic string is named more rapidly than are letters initiating orthographically invalid letter strings. In order to account for such data, the LaBerge and Samuels model would have to assume that the observers were not attending to the initial letter as instructed, but rather, that their attention was directed toward a conceptually higher stimulus, a spelling pattern or the entire letter string. After the attended string had been identified, the observer would read out the individual letters of the string or spelling pattern, after the fact.

GENERAL DISCUSSION

Taken together, Experiments 1 and 2 clarify some of the issues concerning word and letter identification. Based on the present data, it seems unlikely that the elements of a letter string are identified in a left-to-right serial order (Gough, 1972). Evidence favoring simultaneous, parallel processing of letters is twofold. If the identity of a word is obtained through serial identification of its letters, one would expect an appraisable difference in identification time between words (having three to five letters) and single, isolated letters. The results of the naming condition of Experiment 2 suggest that this difference is in fact relatively small and only marginally significant. Serial processing models also experience difficulty in explaining the data from Experiment 2. If the elements of a letter string are processed serially, identification of the string's first letter should not be affected by the sequential order of the letters following it. Yet Experiment 2 has shown that the identification time of a letter string's initial letter is dependent upon the orthographic properties of the entire string.

The data also suggest that words can be identified relatively directly without implementing extensive grapheme-to-phoneme correspondence processes. It was shown that although words and pseudowords differ in articulatory response time by 30 msec, the 72-msec difference in naming time between the two types of

stimuli is too great to be easily explained by response factors alone. It is, therefore, reasonable to conclude that words are identified about 42 msec faster than pseudowords. As noted by Forster and Chambers (1973) and by Frederiksen and Kroll (1976), a likely explanation for such a finding lies in the manner the internal name code or phonetic code of a stimulus is obtained from its visual representation. Pseudowords, being novel stimuli, can be named only after a proper phonetic code is constructed using grapheme-to-phoneme correspondence rules. However, the 72-msec difference favoring words over pseudowords observed here in the naming condition (and the smaller 20-msec difference obtained by Theios and Muise, 1977, when response factors were controlled) suggests that the internal name code of a word can be obtained by direct memory access to a previously established and stored phonetic code without a mediating grapheme-to-phoneme conversion.

A word identification model that can explain the current findings reasonably well is the direct-access memory retrieval system proposed by Theios and Muise (1977). In this model, analysis of the pattern of featural information in the visual display leads directly to various files in long-term memory, where information regarding possible stimuli is stored. Thus the memory files for orthographic, phonetic, and semantic information can all be activated simultaneously, in parallel, and consist of separate processing channels. When asked to name an entire stimulus, observers would operate in the phonetic channel. Since both words and letters have established phonetic codes, they can be identified quickly by directly accessing the phonetic file, and one would not expect a large difference in their naming times. But unfamiliar pseudowords would not have previously established representations in the phonetic memory file, so their codes must be constructed indirectly following spelling-to-sound correspondence routines, resulting in slightly longer pronunciation latencies for pseudowords. The data from Experiment 2 are explained by assuming that when instructed to attend only to letter information, observers can select responses using information in the orthographic memory file. This file is separate from the one containing the phonetic codes, and it holds rules and other knowledge about the orthographic structure of the language. Since words and pseudowords are orthographically regular, the orthographic channel can provide knowledge of orthographic context to assist the readout of the initial letter of a string. Anagrams, however, do not follow valid orthography, so the contextual information in the orthographic channel will not be useful in identifying the anagram's first letter. In short, the Theios and Muise (1977) model is a versatile system allowing the observer to operate on a number of parallel processing channels and to select the processing strategy optimal to the experimental situation at hand, be it naming component letters, reading and pronouncing entire letter strings, making lexicality judgments, or responding on the basis of semantic association.

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