INTRODUCTION

Phonetic recoding effects in silent reading have been reported by a number of investigators employing a variety of experimental techniques (see review by Conrad, 1972) and testing in several languages and orthographic systems (Tzeng, Hung, & Wang, 1977; Erickson, Mattingly, & Turvey, 1977; Navon & Shimron, 1981). While the presence of a phonetic representation in reading has been convincingly demonstrated, the source of the effect and the role of the representation remain largely unexplored. The obvious explanation—that the effect results from a process of grapheme-to-phoneme conversion—is falsified by evidence for phonetic recoding in reading non-alphabetic orthographies (Tzeng et al., 1977; Erickson et al., 1977).

One strategy that might prove fruitful in untangling these puzzles is to specify what linguistic properties are embodied in the phonetic representation constructed by fluent readers. The presence of segmental phonetic features has been firmly established by the studies cited above, but evidence for suprasegmental features, such as word stress and sentence prosody, has not heretofore been sought, though readers' subjective reports suggest that these features are also present. Kleiman (1975) demonstrated an important role for phonetic recoding in the comprehension of written sentences, and since suprasegmentals have been shown to play a role in the perception of spoken utterances, evidence for suprasegmentals in the phonetic representation of written language—which itself marks only the grossest suprasegmental properties of sentences—would be tantalizing evidence for a model of reading based on a strong dependency of reading on speech perception.

In a small pilot experiment using the response bias technique (Mehler & Carey, 1967), the study reported here sought evidence that subjects encode word stress in silent reading on the level of the single word.

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STIMULI

Test items in this experiment were ten words chosen from among those English disyllabic homographs whose syntactic class depends on the placement of primary stress. For example, *content* is a noun when the first syllable is stressed and an adjective (or reflexive verb "to content oneself") when the second syllable is stressed. Similarly, *permit* is a noun when the first syllable is stressed and a verb when the second syllable is stressed. The orthography does not represent the location of word stress for these words; presumably in normal circumstances, sentential context provides the necessary information for choosing in these few ambiguous cases.

Test stimuli were lists composed of eight unambiguously stressed disyllabic words and a ninth, final word taken from the set of homographs. All of the unambiguous words in a single list were matched for placement of primary stress (i.e., all had first syllable stress or all had second syllable stress) but were of varied syntactic and semantic classes.

Test lists were embedded in a series of foil lists consisting of from eight to eleven words chosen at random. The ratio of foil sets to test sets was 7:1, yielding 80 lists.

In a pretest of the test stimuli, 20 subjects were asked to read aloud a list of 200 English words, among which the test words were embedded. Their assignment of stress for the homographs was recorded. Responses to this pretest were used as a baseline measure of preference in the experiment. Results appear in Table 1, Column A. Each test homograph was preceded in the main experiment by a list that shared the stress pattern of its less-preferred reading.

SUBJECTS

Subjects were 18 undergraduate volunteers enrolled in introductory linguistics courses at the University of Connecticut. All were native speakers of English. They were paid for their participation.

PROCEDURE

Subjects were told that the purpose of the main experiment was to measure the effect of reading rate on accuracy of recall. Each subject was tested separately. The subject was seated in front of a computer-controlled CRT screen on which appeared, for each trial, a vertical list of eight to eleven words. The subject was instructed to read each word on the list silently from top to bottom, as quickly as possible without missing any of the words, and to signal the experimenter when he or she was finished by reading the last word on the list out loud. The list on the screen then disappeared and was replaced by a single word. The subject was instructed to respond "yes" if the word was on the preceding list and "no" if it was not. This probe word was never one of the homographs. Subjects' spoken responses were tape-recorded for transcription later. The entire presentation took approximately fifteen minutes.
RESULTS

The results of this experiment are summarized in Table 1. Column A gives the percentage of times that the less-preferred stress pattern for each ambiguous item was given as a response in the pretest and notes whether the less-preferred reading was as a noun (with first syllable stress) or as a verb (with second syllable stress). Column B gives the percentage of the trials in which the less-preferred stress pattern was elicited in the biasing condition. The number of subjects is given in parentheses in this column. Column C gives the percentage of trials in which the less-preferred pattern was elicited from subjects who answered the word recognition question correctly for that test list. The number of subjects who answered correctly appears in parentheses.

Comparison of Columns A and B indicates an effect of the biasing lists on the stress pattern of the ambiguous test items. In a Wilcoxon one-tailed test, this difference was significant at the .05 level.

The biasing effect becomes even more apparent if we take into account subjects' performance on the recognition test. Column C gives the results just for subjects who answered the memory question correctly for the list in

Table 1

<table>
<thead>
<tr>
<th>ITEM</th>
<th>PRETEST (N-20)</th>
<th>BIAS CONDITION</th>
<th>BIAS CONDITION (MEMORY QUESTION CORRECT)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>conduct</td>
<td>10% (initial)</td>
<td>72% (18)</td>
<td>82% (11)</td>
</tr>
<tr>
<td>object</td>
<td>20 (final)</td>
<td>17 (18)</td>
<td>13 (15)</td>
</tr>
<tr>
<td>pervert</td>
<td>40 (initial)</td>
<td>77 (18)</td>
<td>77 (18)</td>
</tr>
<tr>
<td>present</td>
<td>30 (final)</td>
<td>28 (18)</td>
<td>29 (14)</td>
</tr>
<tr>
<td>digest</td>
<td>20 (initial)</td>
<td>39 (18)</td>
<td>38 (16)</td>
</tr>
<tr>
<td>progress</td>
<td>40 (final)</td>
<td>33 (18)</td>
<td>29 (14)</td>
</tr>
<tr>
<td>permit</td>
<td>20 (initial)</td>
<td>33 (18)</td>
<td>46 (11)</td>
</tr>
<tr>
<td>subject</td>
<td>30 (final)</td>
<td>33 (18)</td>
<td>33 (18)</td>
</tr>
<tr>
<td>incline</td>
<td>10 (initial)</td>
<td>0 (17)</td>
<td>0 (17)</td>
</tr>
<tr>
<td>project</td>
<td>30 (initial)</td>
<td>53 (17)</td>
<td>56 (17)</td>
</tr>
</tbody>
</table>
question. Comparison of Columns A and C shows a significant difference at the .01 level.

A further indication that the biasing manipulation was responsible for the effect observed is that a strong correlation \( r = .81 \) was found between performance on the recognition task and number of shifted responses, accounting for 66\% of the variation between subjects. This correlation is graphed in Figure 1. The graph shows a wide range of subject performance. If we look at both ends of this range, at the two least successful and the two most successful subjects, we find that where performance on the memory task was 69-70 per cent, subjects gave the less-preferred reading only 20 per cent of the time, while the two subjects who answered 88 per cent of the recognition questions correctly gave the less-preferred reading 60 per cent of the time.

**DISCUSSION**

The correlation found is open to two interpretations. Under one interpretation, a subject's success in the recognition task is attributable to the amount of attention paid to the task. The more attentive subjects were more likely to have thoroughly read the word lists; thus they were more likely to have recoded the items on the list, and so to have been primed by properties of the code.

Under another more interesting interpretation, the more successful subjects did more phonetic recoding, as evidenced by the high likelihood that they would be primed by a phonetic property of the word lists. An incidental result of this recoding was the ability to better remember what they had read, and thus better performance on the recognition test.

Under the first of these interpretations, attention rather than the requirements of the reading task per se is what determines performance on the recognition test; the evidence found for mental representation of prosody is a by-product of a process, i.e., constructing the phonetic representation, which is perhaps just one of several representations constructed incidentally in the course of performing the experimental task.

Under the second interpretation, phonetic recoding is an integral part of good reading, and so if people are reading well, they must be constructing a phonetic representation. This will then prime pronunciation of the ambiguous item in the absence of contextual cues. The availability of the phonetic representation incidentally facilitates performance on the recognition task. Better recognition results from greater ease of access to or more completeness of the phonetic representation, which may in turn indicate superior reading ability.

The first (attention) explanation suggests that any number of codes results from attending to the list, and does not give any reason to attribute special status to any code. Thus we should expect semantic and orthographic codes, for instance, to affect subjects' performance similarly to the phonetic code in memory tasks of the sort used in this experiment. The pattern of results reported for a similar task employed by Erickson et al. (1977),
Figure 1
suggests that this is not the case; the orthographic and semantic properties of their word lists did not affect performance in a short-term recall task in the same way that the phonetic properties did.

It should be noted that the response shift was not equal for all the items tested. While a large effect was obtained for the words digest, permit, project, conduct and pervert, other items (object, present, progress) exhibited little effect (or even a reverse effect). Incline is the clearest case: in no trial was it possible to bias a subject in the test situation to pronounce incline as a verb, with second syllable stress. The averages given in Column A are for preferred pronunciations across twenty subjects. These figures indicate that one pronunciation of incline, for example, was preferred over the other by eighteen subjects out of twenty. What they do not indicate is how strong each individual's preference is. Though the former is much easier to measure, it provides only a very rough estimate of the latter—which is, of course, what is really relevant to the biasing experiment. The failure of the biasing manipulation for incline may well be due to the fact that while approximately one person out of ten prefers it as a noun, most people may have it in their lexicons only as a verb. For these people, its stress pattern would be completely unshiftable however psychologically real stress patterns are in reading. This suggests that for this kind of experiment it would be quite proper, and indeed optimal, to select words whose baseline frequency is about equal between noun and verb.

The objection might be made that the effect found in the present experiment is merely an artifact of the particular task employed, rather than a reflection of normal reading processes. To make this claim is to say that subjects employed strategies in the performance of this task that were constructed ad hoc for this purpose. But there is no logical requirement for such a strategy to include the construction of a phonetic representation; on the face of it, a visual representation would suffice. Nor is there any reason to expect all subjects to arrive at the same kind of special strategy. Yet the more successful subjects employed a phonetic coding strategy, while those subjects who could not do this did not seem to find another strategy that was similarly effective. Thus it appears that subjects were making the best use they could of reading skills that were already available for more ordinary purposes.

While it might be argued that the phonetic effects found by Conrad (1964) and Baddeley (1966), for example, and in the present experiment are due to rehearsal strategies for short-term recall, which have been shown to employ a phonetic representation (see Baddeley, 1976, Chapter 8, for discussion), this argument does not apply to effects found in the acceptability judgment task employed by Kleiman (1975), which did not require rehearsal. Thus the construction of a phonetic representation cannot be viewed as a mere artifact of rehearsal.

It could also be argued that for semantically integrated sentences, readers might use a semantic code, and employ a phonetic code to facilitate memory only when the items in the experimental sequence do not cohere semantically. The findings of Baddeley and Hitch (1974) address this criticism. They compared reaction times in a grammaticality judgment task using ordinary sentences and sentences composed of phonetically similar (rhyming)
words. Phonetic similarity increased response latencies to grammatical and ungrammatical sentences. This task does not involve rehearsal or short-term memory. But it does implicate the parser, lending support to the conclusion from Kleiman's study that the sentence parsing mechanism requires a phonetic representation, quite apart from any requirements of short-term memory. If subjects construct a fairly detailed phonetic representation in a relatively unnatural situation in which it affords them no apparent advantage, we might also expect them to do it in a more natural situation. In other words, if subjects encode prosody when they read lists of words silently in a task that does not require comprehension, then it is likely that they will also encode prosody when they read ordinary sentences in a task that necessarily invokes the higher level processing involved in comprehension.

An important finding from this experiment is that readers construct a mental representation that includes features not represented in the stimulus. Thus, while it might be maintained that readers of English represent the segmental features of the words they read just because these can be extracted by rule from the letters of the orthographic system (at least in most cases), no such claim can be made for suprasegmental features such as stress, for there are no symbols in English orthography that indicate stress. In the stress-neutral pretest condition, subjects were always able to name the homographs. That this was not accomplished by simply applying rules to translate from orthography to phonology is strongly suggested by the fact that not all words having the same orthographic structure were consistently assigned the same pattern of stress by a single subject. More likely, a bias of some sort, due to factors such as frequency of occurrence, was responsible for a subject's choice in each case. Such a bias could only come from the lexicon. This is true in the case of vowel quality in homographs (lead, bow) as well. For these words, at least, naming written words must follow lexical access.

This must always be the case in naming Chinese logographs and Japanese kanji. These orthographic systems give very little phonological information, yet reading lists of words written in these orthographies results in a phonetic representation in short-term memory (Tzeng et al., 1977; Erickson et al., 1977). Thus almost all phonetic information must be supplied by the reader after lexical access.

Further support for the active participation of the lexicon in reading is provided by Hebrew. The Hebrew language is represented by an alphabetic orthography that keeps the vowel symbols fairly well separated from the consonant symbols. In texts intended for fluent adult readers, the vowel information is usually omitted entirely. However, it is the vowels of Hebrew that represent the inflectional system and carry most of the morphological and syntactic information. The task of the reader in Hebrew is to decide, presumably in the course of parsing procedures, the syntactic role of each word and its morphological composition in that role. Having derived this information, there is no reason to expect the reader of Hebrew to then add information about the vowels that would represent the word in speech. But the results of a study by Navon and Shimron (1981) suggest that they do indeed do so. Their subjects read lists of morphologically simple (uninflected) words in which vowel phonemes were represented by the optional vowel diacritics. Latencies in lexical decision tasks were increased by phonemically anomalous
diacritics but not by graphemically anomalous diacritics that preserved the phonology. The effect could not be attributed to visual factors.

Their results suggest that in the simple case of reading unambiguous uninflected words, with no concurrent processing demands such as those required for sentence comprehension, subjects both construct a phonetic representation and access the lexicon. (In this case, lexical access appears to follow grapheme-to-phoneme translation. However, there is ample evidence, as Navon and Shimron point out, for models of lexical access that include a visual route. In any case, the result is a phonetic representation.) Yet Kleiman's results suggest that it is just in those cases in which processing for comprehension is required that the phonetic representation is important. In the case of fluent readers of Hebrew in the ordinary situation of reading text, the construction of a phonetic representation is at least as likely to occur as in the simple case of lexical decision. However, here the construction of the phonetic representation must follow lexical access, as with English homographs, Chinese logographs, and Japanese kanji. But with Hebrew, it is also likely to be the case that the phonetic representation is the product of the parser, rather than of the lexicon, since it is the analysis resulting from the parsing process that indicates to the reader what the morphology of the word must be, and thus what vowels must be supplied.

The facts about Hebrew, on the one hand, and English, Chinese and Japanese, on the other hand, suggest two hypotheses to account for the effect found in the present experiment. Under one hypothesis, which I will call the lexical bias hypothesis, prosodic priming is a result of activity in the lexicon. There is evidence that stress (or some abstract representation from which stress can be derived by rule [Chomsky & Halle, 1968]) is a feature of lexical entries (Brown & McNeill, 1966), just as segmental phonological features and semantic features are. As such, stress can probably be primed similarly to semantic features (Meyer, Schvaneveldt, & Ruddy, 1975). As the activation of a single word may activate any number of lexical entries in the same semantic field, the activation of a single disyllable with first-syllable stress might activate (if slightly) all disyllables having first-syllable stress. The activation of nine such words may have the cumulative effect of activating the first-syllable-stressed entry for the homograph to a point where it is much more readily available than the second-syllable-stressed entry, and thus more likely to be reported in the priming situation.

The second hypothesis, suggested by the facts about Hebrew, may be called the parsing hypothesis. According to this hypothesis, even isolated words are parsed, that is, they are processed as one-word sentences (see Mattingly, Note 1). It is in the parser that the morphophonemic representation retrieved from the lexicon is assigned a phonetic representation. This type of model is well suited to an orthography such as Hebrew. In fact, if it is assumed that the entire linguistic system, of which word recognition is only a part, is designed for the processing of linguistic structures, this type of model is equally well suited to English and any other language. The prosodic priming effect can then be seen as the result of a bias induced in the parser as it constructs a complete phonetic representation, including prosody, for each of a series of one-word sentences. A small bit of evidence in support of this hypothesis for English is the apparent ease with which sentences containing homographs are read: In syntactic context, the grapheme sequence p-r-o-g-r-e-
s-s (for example) may be instantly recognized as a noun or a verb as a result of information derived by the parser. The entire analysis of the sentence up to the point where the homograph is encountered determines what syntactic categories are likely to occur in a well-formed structure and guides lexical access to the appropriate entry, yielding, ultimately, the appropriate phonetic representation.

REFERENCE NOTE


REFERENCES


