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The Influence of Orthography on Phonological Representations in the Lexicon

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A syllable monitoring task was used to examine the nature of the phonological representation of words in the lexicon. In the first experiment subjects tended to accept a match between the target syllable and the word when the vowel of the target syllable was of full value while the vowel of the word was a reduced vowel. Thus the reduced vowel was accepted as a full vowel as determined by the orthography of the word. The second experiment also provided evidence that the phonological representation involved in performing the task was orthographically influenced. The orthographic syllabic structure of the word appeared to have an effect on reaction times. The results are discussed in terms of the nature of phonological representation and the possible implications for the lexical representation of pronunciation and spelling.

In order for a speech signal to be recognized and understood, the encoded signal must be decoded in some way. There are at least three different levels of decoding that are possible: acoustic, phonetic, and phonemic (phonological). In addition to these levels of coding, there are various different possibilities regarding the amount of signal that is decoded at any one time. The possibilities range from single phones or phonemes through to syllables, whole words, and sentoids (Mehler, Dommergues, Frauenfelder, & Segui, 1981). The concern of this paper, however, lies more with the levels of coding in speech perception than in the size of the perceptual unit.

Foss and Blank (1980) have suggested that whether decoding takes place at a phonetic or a phonological level depends upon whether lexical access has taken place or not. Preaccess effects are seen as phonetic; post-lexical effects are seen as phonological (the Dual Code hypothesis).[1] The rationale for this proposal is that phoneme monitoring times are the same regardless of the frequency of the word in which the phoneme is contained or of the lexical status of the phoneme-bearing item (word or nonword). On the other hand, phonemes contained in words which can be predicted from the preceding context *are* detected more quickly than those contained in unpredictable words. Foss and Blank conclude from this that when there is sufficient top-down information to allow lexical access without complete phonetic information being available, the response can be made on the basis of information stored within the lexical entry, specifically, phonological information. When there are negligible top-down cues available the response must be made on the basis of prelexical information, specifically, phonetic information.

While the data presented by Foss and Blank certainly support the prelexical/postlexical distinction, the concomitant phonetic/phonological distinction seems to be merely conjecture. In fact the use of the terms "phonetic" and "phonological" in this context is not clearly specified. The phonetic representation is described by Foss and Blank as a linguistic code that is constructed from the acoustic signal. However, for subjects to detect that the /t/ of /tə/ occurs at the beginning of both /tɪ:*t*ʃər/ and /tu:tər/, the allophonic variation that exists between the three /t/'s must be ig-

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[1] A similar idea was put forward by Newman and Dell (1978) and Cutler and Norris (1979).

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nored. Thus the term "phonetic" refers here to a level where allophones are not treated as separate entities and is therefore more abstract than its traditional description (e.g., Lyons, 1968).

Of more importance to the concerns of this paper is what is meant by "phonological." Foss and Blank describe the phonological representation as an abstract code stored in the lexicon, but they do not expand on what they mean by the term "abstract." Is the representation a morphophonemic one as suggested by Chomsky and Halle (1968) or is it closer to the surface phonemic representation (e.g., Linell, 1979)?

While the issue of phonological representation in the lexicon has been the subject of much linguistic research, it has received very little attention in the empirical, psycholinguistic domain. It has simply been said that a phonological representation of a word is made available once the lexical entry for that word has been accessed, either on a phonetic basis (e.g., Foss & Blank, 1980) or on a visual basis (e.g., Kleiman, 1975; Coltheart, 1980)—the specific nature of this phonological representation has been largely ignored. The supposition seems to have been that the representation is simply a "silent" version of the pronunciation of the word (i.e., a surface phonemic representation).

However, an alternative possibility is offered by generative phonologists (e.g., Chomsky & Halle, 1968) where the lexical representation is seen as being morphophonemic. By this account, morphologically related words share the same abstract underlying phonemic representation from which their surface phonemic representations are generated by rule application. For example, while the surface phonemic representation of METALLIC is /mətælɪk/, the underlying morphophonemic representation includes the full vowel /ɛ/ rather than a reduced vowel /ə/, since the /ɛ/ manifests itself in the surface phonemic representation of the related word METAL (i.e., /mɛtəl/). Similarly, the underlying morphophonemic representation of MUSCLE includes a /k/ because this sound appears at the surface in the related word MUSCULAR. It should be noted here that the orthography of a word is seen by Chomsky and Halle as often reflecting the morphophonemic representation of that word, but does not itself influence the morphophonemic representation. Thus the morphophonemic form of WHISTLE does not contain a /t/ (even though there is a T in the orthography), since there are no morphologically related words where /t/ is pronounced at the surface level.

The aim of the first experiment to be reported was to examine the nature of the postaccess (i.e., lexical) representation that is used when a decision is to be made about the phonology of a word. Is this representation morphophonemic, surface phonemic, or something else?

Experiment 1

The task employed in this experiment was a monitoring task whereby subjects were required to determine whether or not a particular string of phonemes appeared in an aurally presented word. A similar task has been employed by Mehler, et al., (1981) and Segui, Frauenfelder, and Mehler (1981).

Segui et al. have demonstrated that this syllable detection task taps a prelexical stage of processing, under conditions where the target syllables only ever appear at the beginning of the words. They found that lexical status (word or nonword) did not affect syllable detection times. Mehler et al., however, note that if target syllables can appear anywhere in the words then it is likely that the task will tap postlexical processing. If this is so, then one can examine the nature of the postaccess phonological code by having subjects monitor for a designated syllable anywhere in the word.

If it is the case that the phonological representation is morphophonemic, and if subjects perform the syllable monitoring task at this level (rather than at a surface phonemic level generated by rule from the morphophonemic representation), then one might expect that subjects would incorrectly detect a syllable that occurs in the morphophonemic representation of a word but not in its surface phonemic representation.

For example, the morphophonemic representation of the word /hərαɪzən/ (i.e., HORIZON) begins with /hɔr/ rather than the actual surface form /hər/, because /hɔr/ occurs in the related word /hɔrəzɔntəl/ (i.e., HORIZONTAL). Therefore, if subjects are required to say whether the phoneme string /hɔr/ is heard at the beginning of the word /hərαɪzən/, they may incorrectly say "yes" (or perhaps take a long time to say "no") should they be performing the task at the morphophonemic level. On the other hand, they ought to find it easy to say that /hær/ does not occur at the beginning of /hərαɪzən/. Similarly, subjects should encounter difficulty in saying that /væl/ is not heard at the beginning of /vəlɪdətɪ:/ (i.e., VALIDITY), but should find it easy to make the same response to /vɔl/. If, on the other hand, the task is performed at the surface phonemic level, then there should be no difference in the ease with which /hɔr/ and /hær/ are detected as not occurring at the beginning of /hərαɪzən/, and with which /væl/ and /vɔl/ are detected as not occurring at the beginning of /vəlɪdətɪ:/.

However, data that would support the idea of a morphophonemic representation based on the aforementioned type of item would be open to an alternative interpretation. This alternative possibility is that the task may be influenced by the orthography of the word, even though the subjects are required to make a decision about the pronunciation of the word. Seidenberg and Tanenhaus (1979) and Tanenhaus, Flanigan, and Seidenberg (1980) have presented evidence to support the idea that orthography can play a role in an ostensibly phonetic task. For example, subjects were required to determine whether a pair of words rhymed or not and it was found that rhyming pairs that were orthographically different (e.g., TURN LEARN) took longer to respond to than rhyming pairs that were orthographically similar (e.g., TURN BURN). Thus, despite the phonetic nature of the task there was a clear orthographic influence.

In order to differentiate between the morphophonemic view and the orthographic view, a second group of items was used in the present task. These items were similar to the other ones, except that the full value of the reduced vowel could not be determined on the basis of morphemic alternations. The only way that the full value of the reduced vowel could be known in these cases would be from the orthography. For example, there is no word related to /ləgu:n/ (i.e., LAGOON) that would suggest that its morphophonemic representation should begin with /læg/. Therefore, the morphophonemic representation of /ləgu:n/ should, according to Chomsky and Halle, begin with /ləg/. So if subjects are performing the syllable detection task at a morphophonemic level, uninfluenced by orthography, they should be able to say that /læg/ does not occur at the beginning of /ləgu:n/ with the same ease with which they can say that /lɔg/ does not occur at the beginning of /ləgu:n/. If on the other hand, these sorts of items show the same pattern of results as the other sort (i.e., where morphologically related forms give a clue to the full value of the vowel), then the conclusion must be that the level at which subjects are performing the task is influenced by orthography.

Method

Subjects. Six subjects were used in each of two groups, making 12 subjects in all. They were all undergraduate students at the University of New South Wales.

Materials. Two groups of 30 words recorded on audiotape were used as experimental items. The first vowel of each of these words was the reduced vowel /ə/.

Each word was preceded by a target phoneme string which consisted of the first two consonants of the word surrounding a vowel of full value. This vowel was either consistent with the spelling of the reduced vowel (e.g., /væl/ /vəlɪdətɪ:/, i.e., VAL VALIDITY) or inconsistent (e.g., /vɔl/ /vəlɪdətɪ:/, i.e., VOL VALIDITY). In the first group of items (the M group), the full value of the reduced vowel could be determined from morphologically related forms (e.g., from the /væl/ of /væləd/, i.e., VALID). For the other group (the O group) orthography was the only indicator of the full vowel (e.g., /ləgu:n/, i.e., LAGOON).

The experiment was designed in such a way that no subject received the same word under both target conditions (i.e., "consistent" and "inconsistent"). One group of subjects heard, for example, VAL VALIDITY ("consistent") and HAR HORIZON ("inconsistent"), while a second group of subjects heard VOL VALIDITY ("inconsistent") and HOR HORIZON ("consistent"). Thus there were two separate tapes used, one for each group of subjects, each tape having 15 items in each of the four experimental conditions (M consistent, M inconsistent, O consistent, O inconsistent).

In addition to these 60 experimental items (which are presented in the Appendix) there were 90 distractor items. Sixty of these required a "yes" response (i.e., the phoneme string did occur in the following word). The target sound occurred at the beginning of 30 of these items (e.g., /dɔm/ /dɔməneɪt/, i.e., DOM DOMINATE), at the end of 15 of them (e.g., /tɪk/ /plæstɪk/, i.e., TIC PLASTIC), and in the middle of 15 of them (e.g., /rƐn/ /pərƐnθəsəs/, i.e., REN PARENTHESIS). The remaining 30 distractor items required a "no" response (as did the experimental items), and were clear cases where the target did not appear anywhere in the word (e.g., /tɔl/ /æləkeɪt/, i.e., TOL ALLOCATE; /dɪg/ /dɔgmætɪk/, i.e., DIG DOGMATIC).

The tapes were recorded in the following way. Tape 1 was recorded so that there were 15 items in each of the four experimental conditions. These were recorded on one channel in a random order interspersed with the 90 distractor items. An item consisted of a target phoneme string, followed by approximately 1 second of silence, the phoneme string repeated, and then after another 1 second of silence, the word. On the second channel, a tone was placed at the beginning of each word serving to trigger a timing device. Tape 1 was then duplicated in its entirety onto Tape 2 for use in the experiment. Tape 1 was then spliced. The repeated presentations of the target syllable were removed (e.g., /væl/ /væl/) and replaced by two presentations of the matching target syllable (e.g., /vɔl/ /vɔl/). In this way, the recording of the word to be responded to, along with the triggering tone on the other channel, was kept intact across both members of each "consistent"/"inconsistent" pair.

So the result of this method of tape construction was that Tape 2 was untouched by splicing, whereas all of the experimental items on Tape 1 were constructed by splicing. Thus if splicing proved in any way to be detrimental to the ease with which a response could be made to a word, this would be true for the same number of items in each of the four conditions.

Procedure. Items were presented to subjects via headphones using a Revox PR99 tape recorder. Subjects were instructed to press a "yes" response key if the *exact target sound* appeared anywhere in the word, and if not, to press the "no" response key. It was emphasized that the target was a sound and that the exact sound had to be located in the word for "yes" to be correct.

A computer timer was set off by the tone which was placed at the start of the word, but on the second channel of the audiotape. Subjects did not hear this second channel. Depression of a response key stopped the timer, thus recording reaction time and type of response ("yes" or "no") for each trial.

Results

The percentage of errors made in the four conditions (i.e., responding "yes, the syllable was heard in the word") are presented in Table 1.

Using a 2 × 2 Analysis of Variance, it was found that there was a highly significant main effect of consistency in both the subject and item analyses [$F_1(1,8) = 106.42$, $p < .001$, $F_2(1,58) = 133.59$, $p < .001$], but neither the difference between the M items and O items nor the interaction between consistency and the M/O factor was significant, ($p > .1$ in each case).

Although reaction time measurements were recorded, these turned out to be meaningless because of the very high error rate on the "consistent" items. In fact for 37% of these items the mean reaction time could not be calculated, since every subject responded incorrectly.

Discussion

From these results it is clear that the level at which subjects are performing the task is one where reduced vowels are treated as full vowels. Further, it is apparent that the full value of the vowel is determined by the orthography of the word and not by virtue of the existence of morphologically related forms that themselves include the full vowel. Thus the word LAGOON is perceived as beginning with the phoneme string /læg/ even though it actually begins with /ləg/. There is no reason to believe that LAGOON begins with /læg/ other than that the word is spelt with an A.

There are two possible artifacts, however, that need to be discussed before these conclusions can be accepted. First, it happens to be the case that the vowels appearing in the target syllables are not well matched between the "consistent" and "inconsistent" conditions. The vowel /ɪ/ appears far more often in the "inconsistent" items than in the "consistent" items, while the reverse is true for /ɛ/. Therefore, if it were the case that subjects confused /ɛ/ with /ə/ more often than they confused /ɪ/ with ə/ then this would influence the "inconsistent" and "consistent" conditions differently and might account for the present results. However, an examination of the performance of subjects on each of the vowels does not support this possibility. The mean number of errors on targets with /ɛ/ was 81% for "consistent" items (n = 22) and 35% for "inconsistent" items (n = 12), while for targets with /ɪ/ it was 82% for "consistent" items (n = 6) and 21% for "inconsistent" items (n = 20). For targets with /æ/ the means were 72% (n = 20) compared to 16% (n = 16), and for targets with /ɔ/ they were 73% (n = 12) compared to 25% (n = 12). Thus there appears to be a strong consistency effect regardless of the vowel.

The second possible problem is that many of the words used in the experiment may not actually be pronounced with a fully reduced vowel, not only by the speaker on the tape but by the subjects themselves. In an effort to provide evidence against this possibility, the speaker on the tape plus four other Australian speakers each recorded the list of words used in the experiment, speaking in a normal clear voice. These recordings were then presented to three professionally trained phoneticians

TABLE 1
PERCENTAGE ERRORS FOR THE FOUR EXPERIMENTAL CONDITIONS OF EXPERIMENT 1

	Consistent	Inconsistent
M items	e.g., /væl/ /vəlɪdətiː/ 73.3%	e.g., /vɔl/ /vəlɪdətiː/ 21.2%
O items	e.g., /læg/ /ləguːn/ 75.5%	e.g., /lɔg/ /ləguːn/ 25.2%

who were asked to note any of the words whose first vowel they did not believe was fully reduced. The data obtained from these ratings revealed that all judges thought that three of the speakers did not pronounce HORRIFIC with a reduced vowel, and two judges thought that one speaker did not reduce the E of GERANIUM, but otherwise all of the putative reduced vowels were perceived as /ə/. It therefore appears safe to conclude that the effect observed in this experiment was the result of an orthographic influence rather than the result of an artifact.

There are two possibilities as regards the level at which subjects are performing the syllable monitoring task. First, it may be that the target phoneme string and the following word are both translated into an orthographic representation (the former presumably by sound-to-spelling rule conversion, and the latter by means of lexical information stored about the spelling of the word). The task is then performed at an orthographic level. It seems odd, however, that subjects would adopt such an approach in a purely phonological task, though it is possible that the orthographic level is brought into play as a last resort when the phonemic level fails to provide a positive match.

The second possibility is that the task is performed at an abstract phonological level, but where the phonological representations are influenced by orthography. Such a view has been previously advocated on linguistic grounds, for example, Moskowitz, 1973; Kerek, 1976. The suggestion is that once a language user learns to spell, his knowledge of orthography fundamentally alters his phonological representations (see also, Ehri & Wilce, 1980). Such an explanation seems preferable to the purely orthographic account since it proposes that the phonological task is performed at a phonological level. However, to empirically discriminate between the two accounts appears difficult. What might possibly support the orthographically-influenced phonological account over the purely orthographic one, might be the finding of an orthographic influence for "yes" responses; that is, in circumstances where the task could be successfully performed at the phonological level. Such a situation was included in the second experiment.

Experiment 2

The orthographic factor that was manipulated in Experiment 2 for the "yes" responses was the orthographic syllabic structure. Taft (1979) proposed the notion of a Basic Orthographic Syllabic Structure (or BOSS) whereby the syllabification of a visually presented word is guided by orthographic (and morphological) principles rather than by phonetic ones. The BOSS of a word (its orthographically defined first syllable) includes all of the consonants following the first vowel, regardless of the pronunciation of the word. For example, the BOSS of GOSPEL is GOSP even though the phonetic syllabification of GOSPEL is not GOSP/EL (but rather, is GO/SPEL, GOS/PEL, or perhaps GOS/SPEL).

If the phonological representation of a word is modified by the orthography of that word, then it is possible that orthographic syllabic structure is expressed in this representation. If so, one would expect that a target syllable that coincided with the BOSS of a word would be detected in that word more readily than a target syllable that did not coincide with the BOSS. For example, the target phoneme string /gɔs/ should be easier to detect in the word /gɔsəp/ (i.e., GOSSIP) than in the word /gɔspəl/ (i.e., GOSPEL), even though these two words have the same phonetic syllable structure, since /gɔs/ is the BOSS of the former but not of the latter (where /gɔsp/ is the BOSS). Similarly, the target /vɪ:/ should be detected more readily in the word /vɪ:əkəl/ (i.e., VEHICLE, whose BOSS is /vɪ:/) than in the word /vɪ:toʊ/ (i.e., VETO, whose BOSS is /vɪ:t/), even though the first phonetic syllable of both words is /vɪ:/.

Such a finding would be compatible with the view that says that the lexical phonological representation is influenced by orthographic structure, and not with the view that says that the syllable detection task is performed at an orthographic level when a match at the phonological level is unsuccessful. When the target syllable does occur in the word (as is the case here), a phonological match should not be unsuccessful.

It should be noted that a failure to observe a BOSS effect in this experiment would not necessarily endorse the purely orthographic account. It may be that the BOSS has no unique psychological status (see Lima & Pollatsek, 1983), or that, if it has, it is not one of those orthographic factors that modifies the phonological representation.

In addition to looking at the BOSS effect in this experiment, two other comparisons were examined. The first of these was a modification to the "inconsistent"/"consistent" comparison for "no" responses made in the first experiment. Items were used where the orthographic translation of the target syllable was contained in the orthographic translation of the following word, but the target syllable itself, in its phonetic form, was not contained in the word. Reduced vowels were not involved. For example, the syllable /bʌl/ is not phonologically present in the word /bʊlət/ (i.e., BULLET), though its orthographic transcription, BUL or BULL, does occur in the spelling of BULLET. The existence of an effect of orthographic consistency can therefore be gauged by comparing the ease of making a "no" response to /bʌl/ /bʊlət/ with that to /bɔl/ /bʊlət/, where /ʌ/ is not phonetically more similar to /ʊ/ than is /ɔ/. Similarly, /wɪst/ /wɪsəl/ (i.e,. WHISTLE) should be a more difficult item than /wɪsk/ /wɪsəl/.

The final comparison made in this experiment was included to ascertain whether the "yes" responses were being made at a preaccess or postaccess stage. It is possible for orthographic effects to result from a preaccess stage of processing via the application of sound-to-spelling conversion rules, although this seems somewhat unlikely given the complexity of the rules required. The stage of processing (pre- or postaccess) was determined by looking at the frequency effect, using the same logic as Foss and Blank (1980). If, for example, /bæl/ was detected in /bæləd/ (the low frequency word BALLAD) as quickly as it was in /bæləns/ (the higher frequency word BALANCE) it must be the case that the task was being performed at a preaccess stage. If on the other hand, detection times for BALLAD were found to be longer than those for BALANCE, then it follows that the syllable was being detected on the basis of lexical information (i.e., postaccess).

In summary, then, the second experiment to be reported looked at three things:

1. A BOSS compatibility effect, to determine if the auditory task was influenced by orthographic syllabic structure.
2. An interference effect, to determine whether or not the orthography of a word led to difficulties in deciding that a target syllable was not phonologically present within that word.
3. A frequency effect, to determine whether any effects observed were likely to be prelexical or postlexical.

Method

Subjects. Subjects in the experiment were 16 undergraduate students. Each subject was randomly assigned to one of two groups.

Materials. Subjects were presented with 60 experimental items, making up three different comparisons. As in the first experiment, each trial consisted of a target syllable recorded twice, followed by a word. The three comparisons were designed in the following way.

1. Twenty word pairs were obtained where each member of a pair began with the same phonetic syllable, for example, /gɔsəp/ (i.e., GOSSIP) and /gɔspəl/ (i.e.,

GOSPEL). These words were preceded by a target phoneme string that was the same as the BOSS of one member of the pair (B condition: e.g., /gɔs/ /gɔsəp/), but did not coincide with the BOSS of the other member (NB condition: e.g., /gɔs/ /gɔspəl/). The B condition items were matched overall with the NB condition items on frequency of occurrence according to Carroll, Davies, and Richman (1971). Other examples of pairs are MINISTER (B condition) and MINSTREL (NB condition); VEHICLE (B) and VETO (NB). The target syllable was never a word in its own right[2] (e.g., /gɔs/, /mɪn/). Each subject heard only one member of each pair. Thus, there were two separate groups of subjects, one group receiving, for example, MINISTER (B condition) and GOSPEL (NB condition), while the other received MINISTREL (NB condition) and GOSSIP (B condition). The method of recording the two audiotapes (one for each group) will be described later.

2. Twenty further words were designed in a similar way to the experimental items of Experiment 1, except that the vowel of the first syllable was never a reduced vowel. There were two types of target syllables, differing from each other in the relationship of their orthographic transcription to the orthography of the word which followed them. In one case, the syllable could be spelled in the same way as the beginning of the word ("consistent" condition: e.g., /bʌl/, able to be spelled as BUL or BULL, followed by /bʊlət/, i.e., BULLET), while in the other, the syllable could not have the same spelling as the beginning of the word ("inconsistent" condition: e.g., /bɔl/ followed by /bʊlət/). Items were designed so that the "consistent" and "inconsistent" items were matched overall on the number of phonetic features they had in common with the beginning of the following word (according to Chomsky & Halle, 1968). Other examples of item pairs are /wɪst/ /wɪsəl/, that is, WHISTLE ("consistent") and /wɪsk/ /wɪsəl/ ("inconsistent"); /lɪ:θ/ /lƐðɐ/, that is, LEATHER ("consistent") and /leɪθ/ /lƐðɐ/ ("inconsistent"). Again, subjects were presented with only one member of each item pair.

3. Twenty word pairs were constructed so that each member of a pair began with the same target phoneme string as the other member, but one member was a high-frequency word (HF condition) and the other was a low-frequency word (LF condition). Examples of such pairs are /bæləns/ (the HF word BALANCE) and /bæləd/ (the LF word BALLAD); /æpəl/, that is, APPLE (HF) and /æpəθɪ:/, that is, APATHY (LF); /rɪ:dʒən/, that is, REGION (HF) and /rɪ:dʒənt/, that is, REGENT (LF). As with the B and NB conditions, the target syllable was always a nonword (e.g., /bæl/, /æp/). Again, each subject heard only one member of each pair.

In addition to the 60 experimental items, (which are presented in the Appendix) there were 40 distractor items. Ten of these were where the target sound was at the end of the word (e.g., /tɪk/ /plæstɪk/), 10 where the target sound was in the middle of the word (e.g., /rƐn/ /pərƐnθəsəs/), and 20 where the target was not in the word at all (e.g., /tɔl/ /æləkeɪt/). Both groups of subjects heard the same 40 distractor items.

The tapes were recorded in the same way as in the first experiment, except that for the BOSS and frequency comparisons a different splicing technique was used on Tape 1. For the B, NB, HF, and LF conditions, the nontarget part of the word was removed (e.g., the /əns/ of /bæl/ /bæl/ /bæləns/) and replaced by the nontarget part of its matching word (i.e., /əd/, spliced from a recording of /bæləd/), thus creating a new recording of /bæl/ /bæl/ /bæləd/. By splicing the tape in this way, the two presentations of the target syllable, the tone on the second channel and the target in the word,

[2] In preliminary work, it appeared that targets that were words (e.g., the PILL of PILLOW) were treated differently than targets that were not words. Why this might be so is a question that may be worthy of further research.

TABLE 2
MEAN SUBJECT RESPONSE TIME (msec) AND PERCENTAGE ERROR FOR THE THREE COMPARISONS OF EXPERIMENT 2

Condition	Example	RT	% Error
HF	/bæl/ /bæləns/	695	3.1
LF	/bæl/ /bæləd/	800	3.8
B	/gɔs/ /gɔsəp/	721	1.3
NB	/gɔs/ /gɔspəl/	794	6.9
Consistent	/bʌl/ /bʊlət/	967	15.0
Inconsistent	/bɔl/ /bʊlət/	852	6.3

were all held constant across both members of each HF/LF pair and each B/NB pair.

Procedure. The procedure was the same as that followed in Experiment 1.

Results

Reaction times and error rates for the six experimental conditions are provided in Table 2.

Looking at reaction times, it was found that all three comparisons were significant: the HF condition was faster than the LF condition on both the subject analysis, $F_1(1,14) = 18.25$, $p < .001$, and the item analysis, $F_2(1,19) = 13.77$, $p < .01$; the B condition was faster than the NB condition, $F_1(1,14) = 12.91$, $p < .01$, $F_2(1,19) = 5.23$, $p < .01$, and the "consistent" condition was slower than the "inconsistent" condition, $F_1(1,14) = 8.58$, $p < .02$, $F_2(1,19) = 13.49$, $p < .01$.

Turning to errors, the frequency effect was not significant, ($p > .1$ for both F_1 and F_2), the BOSS effect was only significant on the subject analysis, $F_1(1,14) = 11.12$, $p < .01$, $F_2(1,19) = 2.66$, $p < .1$, and the orthographic interference effect was significant on both analyses, $F_1(1,14) = 7.22$, $p < .02$, $F_2(1,19) = 6.17$, $p < .05$.

Discussion

The finding of a significant frequency effect on reaction times means that the syllable monitoring task was being performed on the basis of lexically stored information. In other words, any effects observed in this experiment are likely to be postaccess effects. This result is in contrast to that obtained by Segui et al. who failed to find a difference in response times to words and nonwords, thus implying that responses were being made prior to access. Targets always occurred at the beginning of their words. Mehler et al. suggest that if the target syllables were to be monitored anywhere in the word rather than just at the beginning, then postaccess effects would emerge.

This suggestion is consistent with the present results since targets could indeed appear anywhere in the word. It follows then, that the frequency effect (and the BOSS effect) obtained in Experiment 2 should be eliminated if the experiment were to be modified by having the targets appearing only in initial position. We in fact attempted to do this using the same experimental items, but obtained exactly the same results as when the target could appear in any position. Thus it remains unclear what it was about the technique used by Mehler et al. and Segui et al. that allowed subjects to respond prelexically. Perhaps it is not as much a difference in techniques as a difference between French subjects (as used by Mehler et al. and Segui et al.) and English subjects. Cutler, Mehler, Norris, and Segui (1983) have demonstrated that French subjects give a different pattern of results in a syllable detection task than do English subjects, irrespective of whether the words used are French or English.

The BOSS effect obtained in the present experiment first supports the psychological status of the BOSS (as opposed to Lima & Pollatsek, 1983) and second suggests that orthographic syllabic structure influences the phonological representation. If the task is being performed at an orthographic level rather than at an orthographically modified phonological level, then this is happening even when a phonological match of target and word could succeed. Such a view ascribes to orthography a dominating role in spoken word processing that seems unnecessary given the alternative of an orthographically influenced phonology.

Arguments may perhaps be made, however, that the B/NB difference is not a result of orthographic syllabic structure, but of some artifact. It is possible that the NB items are affected by coarticulation in a way that the B items are not. The second consonant of the medial consonant cluster of the NB items (e.g., the /p/ of /gɔspəl/) may influence the articulatory characteristics of the first consonant of this cluster (i.e., the /s/ of /gɔspəl/), since coarticulation effects have been demonstrated to perceptibly occur across syllable boundaries (Martin & Bunnell, 1982). Thus it may be argued that the target syllable is aurally less distinct in the NB items than in the B items. The counterargument, however, is that by the method of splicing used in this experiment, the NB items on one of the tapes (Tape 1) were all constructed from recordings of B items, and the B items on this tape were all constructed from recordings of NB items. Therefore, any systematic disturbance that might have been caused by coarticulation effects should not have been observed on this tape. In fact the strength of the BOSS effect was exactly the same on Tape 1 (the spliced tape) as on Tape 2 (the unspliced tape), being a 73.5-millisecond difference for the former and a 73.2 millisecond difference for the latter.

It should be noted that there were two NB condition words in the experiment where the final consonant of the target was not uniquely represented in the orthography. These were /æŋk/ /æŋkʃəs/ (i.e., ANXIOUS) and /ɔ:t/ /ɔ:tʃəd/ (i.e., ORCHARD). Difficulty in responding to these two items could arise from general orthographic effects independent of orthographic syllabic structure, since ANK is not orthographically contained in ANXIOUS, nor ORT in ORCHARD. It might possibly be argued that the B/NB reaction time difference that was obtained in this experiment was largely a result of these two uncharacteristic items, particularly since the item analysis was not strongly significant. However, if the item analysis is carried out without the /æŋk/ and /ɔ:t/ items, the F value actually increases, $F(1,17) = 8.94$, $p < .01$. This seems to happen because many subjects made errors on these items rather than taking a long time to make the correct decision. In fact, 64% of the errors made in the NB condition were made on these two items[3] (which is the reason why the item analysis of the errors was not significant). Therefore, it appears that an incompatibility between the orthography of the target and the orthography of the target bearing word leads to major difficulties which result in errors; whereas incompatibility between the target and the orthographic syllabic structure of the word leads to a slowing down of the response. However, either way, the main point is that there is an orthographic influence on the "yes" responses.

Turning now to the "no" responses, an orthographic effect was again observed, with the "consistent" items being more difficult than the "inconsistent" items as measured by both reaction time and errors. Therefore, the effect extends beyond the reduced vowels used in Experiment 1. The difficulty caused by the "consistent" items, however, was clearly not as great as that encountered in the reduced vowel situation, where there was a massive error rate. This may have come about because of some interesting difference in lexical representation between reduced vowels and other phonemes, but it could equally as likely have resulted from a checking procedure occurring just prior to the making of the "yes" or "no" decision. This check could be made on the strength of a phonetic match using the representation stored in echoic memory, or alternatively by basing it on the pronunciation of the word generated either from the underlying phonemic representation or from a separately stored

[3] It may be argued that the CH of ORCHARD does not contain a /t/ (as in /ɔ:t/) but is a single indivisible phoneme; however, it should be pointed out that, first, the word /ɔ:tɔpsɪ:/ (i.e., AUTOPSY) was able to be created by splicing /ɔpsɪ:/ onto the first part of ORCHARD, and second, four of the eight subjects did respond affirmatively to /ɔ:t/ /ɔ:tʃəd/.

articulatory program that is there for the purposes of overt production. The phonetic similarity between /ə/ and any of the full vowels is greater than that between the full vowels and consonants used in the second experiment (e.g., between /ʌ/ and /ʊ/, as in /bʌl/ /bʊlət/, and /t/ and /ø/ as in /wɪst/ /wɪsəl/). Therefore, at the checking stage, the phonetic match between the target and the word in the first experiment may have been sufficiently close to confirm the match already made at the orthographically influenced phonological level, whereas the poor phonetic match between the target and the word in the second experiment may have overridden the positive match made at the phonological level.

General Discussion

Foss and Blank have argued that postaccess phoneme monitoring is performed at a phonological level. The results of the present experiments suggest that this level is not simply a surface phonemic level nor is it a morphophonemic level as envisaged by Chomsky and Halle. Instead it appears to be an abstract level that is influenced by orthography. Of course, it can always be argued that there *are* morphophonemic representations of words in the lexicon (uninfluenced by orthography), but their existence is not manifested in phonological tasks; that is, competence is not reflected in performance. Even if this were the case, the interest here is in the nature of the phonological representation employed in language processing and, at least in the syllable monitoring task, there is no evidence for a morphophonemic influence.

Is there any evidence for it in other empirical studies? Steinberg (1973) tested subjects usage of one of the rules proposed by Chomsky and Halle to convert the underlying morphophonemic representation into a surface phonemic representation. This is the vowel shift rule that shortens the vowel in morphemic alternations like /sərɪ:n/ → /sərƐnətɪ:/, that is, SERENE → SERENITY, and /koʊn/ → /kɔnɪk/ that is, CONE → CONIC. In Steinberg's experiment, subjects were first presented with an English word which they pronounced (e.g., TROMBONE) and then were required to convert it either into an adjective by adding -IC or into a noun by adding -ITY. What was observed was that only about 3% of the pronunciations given by subjects followed the vowel shift rule; for example, most subjects said /trɔmboʊnɪk/ rather than /trɔmbɔnɪk/. Therefore, it appeared that the vowel shift rule was not productive, hence opposing the idea that there exist underlying representations that require this rule in order to produce surface pronunciations. However, by presenting the root words separately from their suffixes, Steinberg may have artificially biased the subjects' responses. In fact, Crowder (1982, p. 163) reports that he has presented subjects with the complete suffixed item to pronounce (e.g., TROMBONIC) and found that use of the vowel shift rule under these conditions can be as high as 70%.

A demonstration of the productivity of a transformation rule like the vowel shift rule, however, does not prove the existence of a morphophonemic level of representation. It may instead demonstrate the nature of spelling-to-pronunciation conversion rules that might be used to pronounce nonsense words. For example, subjects may simply tend to give a short pronunciation to single vowels contained in a nonsense word, unless there is a silent E suggesting that it should be a long vowel.

Similarly, Smith and Baker (1976) have examined Chomsky and Halle's stress assignment rules that depend on the length of the vowel, the number of final consonants in the syllable, the number of syllables in the word, and the part of speech of the word. An examination of pronunciations produced under various orthographic conditions (e.g., NODUD, NODUDE, NODDUD, and NODOOD) revealed a pattern of stress assignment that was consistent with Chomsky and Halle's rules to some extent. However, Smith and Baker conclude that the data point more to the use of orthographic information in assigning stress than to the use of underlying morphophonemic representations.

An experiment demonstrating the influence of morphological structure on a phonological task was performed by Taft (1984). When subjects were required to say whether a visually presented word was exactly homophonous with another word in English, they made many errors when the two words differed in morphological structure, for example, COWARD and COWERED, but only when they performed the task silently. When they could say the words aloud, the difficulty encountered with these morphologically different words vanished. This finding suggests a level of phonological representation that incorporates morphemic structure and which is different from the surface phonemic representation generated when overt pronunciation is required. Such an abstract representation is compatible with the morphophonemic representation envisaged by Chomsky and Halle. However, it is also compatible with an orthographically influenced phonological representation as long as this representation also includes morphemic structure (see Taft, 1984). Therefore, to date there appears to be no evidence in the psychological literature that unambiguously supports a morphophonemic level of representation as Chomsky and Halle envisage it.

The explanation given here for the influence of orthography on a phonological task (viz. in terms of an orthographically influenced phonological representation) is not unlike that given by Ehri and Wilce (1980) for their finding that phonemic segmentation is influenced by orthographic factors. They propose that knowledge of orthography shapes one's conceptualization of phonemic structure. However, this explanation is not the one given by Seidenberg and Tanenhaus (1979) for their finding of an orthographic influence on a rhyming task, and by Tanenhaus et al. (1980) for their finding of orthographic priming in a Stroop interference task when the prime word is presented aurally. These authors propose that once lexical access takes place, both phonological and orthographic codes are automatically activated and both play a role in the decision to be made about the word that has been accessed. This interpretation differs from the one favored in this paper in that the phonological and orthographic codes are viewed by these authors as separate entities rather than forming an amalgamated representation from which both the pronunciation and the spelling of the word can be generated.

Why do we prefer to say that the orthographic influence on the phonological task results from an orthographically influenced phonological representation rather than from the automatic activation of an orthographic code? In the syllable monitoring task, the automatic activation of an orthographic representation of the presented word is of no use unless the target phoneme string is also converted into an orthographic code. Such a conversion cannot result from automatically activated information stored within the lexical entry for that phoneme string, since the phoneme string has no lexical entry. Instead the conversion presumably comes about through sound-to-spelling conversion rules. To maintain the argument that the task is performed under the influence of an automatically activated orthographic representation, one needs to further say that the application of sound-to-spelling conversion rules also automatically occurs. Since there is no evidence to say that this does not happen, the interpretation that one favors ultimately depends on how dominant a role one wishes to ascribe to orthography in spoken word processing. In one interpretation (the one favored here) the phonological task is performed in a phonological code, though this code is influenced by orthography; in the other interpretation, the task is performed in both a phonological and an orthographic code, with the latter interfering with the former.

The proposition that there are orthographically influenced phonological representations in the lexicon leads to the possibility that pronunciation and spelling are generated from these representations, and are not fully stored in their own right. If this were so, there would need to be a set of transformation rules that were used in converting the underlying representation into the correct pronunciation and these would be something like the grapheme–phoneme conversion rules that have been postulated for phonemic recoding in visual word recognition (e.g., Gibson, Pick, Osser, & Hammond, 1962; Venezky, 1970). Where there was more than one possible conversion (e.g., g → /g/ or /dʒ/) there must be additional information stored within the entry to allow for the correct pronunciation to be made. If one assumes that consultation of this additional information slows down processing time then one can possibly account for the finding that words with an inconsistently pronounced orthography (e.g., BEAD, where EAD has more than one pronunciation) take longer to name than consistent words like BEAN (Glushko, 1979; Andrews, 1982).

Derivation of the spelling of a word from this underlying representation should be more straightforward, since the relationship between the orthographically influenced phonological representation and the orthography would be more isomorphic than between the orthographically influenced phonological representation and the overt pronunciation. However, there would nevertheless need to be some special additional information stored within the entry, for situations where the abstract phonological representation could not differentiate between two different spellings. For example, doubling of consonants might be difficult to represent in the phonological representation, thus leading to spelling confusions. Similarly, the choice between EI and IE might be hard to represent. The additional information required in this case could be the well-known "I before E, except after C" rule. Spelling errors, then, could arise from several sources: failure to develop an accurate orthographically influenced phonological representation, failure to store additional information, or incorrect use of this additional information.

In conclusion, the results of the experiments reported in this paper support a post-access level of procesing that is orthographically affected, even though the task is an auditory one. The results do not appear to bear upon issues regarding preaccess speech processing (e.g., Is it phonetic? What is the perceptual unit?), but they do have implications for issues regarding the nature of the lexical representation.

APPENDIX

The following are the items used in Experiment 1 along with their percentage error rates.

M Condition Items

Word	*"Consistent"*	*Target*	*"Inconsistent"*	*Target*
catastrophe	/kæt/	60	/kɪt/	0
laboratory	/læb/	60	/lɪb/	0
ridiculous	/rɪd/	100	/rɛd/	25
neglect	/nɛg/	100	/nɪg/	0
morality	/mɔr/	100	/mær/	0
demonic	/dɛm/	80	/dɪm/	0
finale	/fɪn/	100	/fæn/	60
potential	/pɔt/	40	/pɛt/	20
balloon	/bæl/	60	/bɪl/	0
validity	/væl/	60	/vɔl/	0
majority	/mædʒ/	100	/mɪdʒ/	0
command	/kɔm/	20	/kæm/	25
saliva	/sæl/	100	/sɛl/	20
senility	/sɛn/	60	/sɔn/	60
photography	/fɔt/	100	/fæt/	0

terrific	/tɛr/	60	/tɪr/	25
horrific	/hɔr/	80	/hɛr/	0
celebrity	/sɛl/	80	/sɪl/	60
paternal	/pæt/	80	/pɛt/	0
marine	/mær/	100	/mɔr/	20
perennial	/pɛr/	60	/pær/	0
democracy	/dɛm/	80	/dæm/	0
mature	/mæt/	80	/mɔt/	80
fallacious	/fæl/	75	/fɔl/	60
metallic	/mɛt/	100	/mɔt/	20
horizon	/hɔr/	75	/hær/	40
symmetrical	/sɪm/	50	/sɛm/	80
necessity	/nɛs/	80	/nɪs/	0
heroic	/hɛr/	80	/hær/	20
melodic	/mɛl/	100	/mɪl/	20

O Condition Items

Word	*"Consistent" Target*		*"Inconsistent" Target*	
parade	/pær/	80	/pɪr/	0
vanilla	/væn/	100	/vɪn/	20
giraffe	/dʒɪr/	100	/dʒɛr/	100
meringue	/mɛr/	100	/mɪr/	0
tobacco	/tɔb/	80	/tæb/	20
verandah	/vɛr/	100	/vɪr/	20
divinity	/dɪv/	100	/dæv/	0
potato	/pɔt/	40	/pæt/	0
canal	/kæn/	100	/kɪn/	0
lagoon	/læg/	60	/lɔg/	0
patrol	/pæt/	80	/pɪt/	20
soprano	/sɔp/	100	/sæp/	40
calamity	/kæl/	25	/kɔl/	0
merino	/mɛr/	80	/mɔr/	20
tomato	/tɔm/	80	/tɛm/	0
phenomenon	/fɛn/	100	/fɪn/	20
molasses	/mɔl/	60	/mɛl/	40
semester	/sɛm/	100	/sɪm/	75
tarantula	/tær/	80	/tɛr/	75
banana	/bæn/	20	/bɔn/	0
negotiate	/nɛg/	100	/næg/	20
veneer	/vɛn/	80	/væn/	25
safari	/sæf/	80	/sɔf/	40
taboo	/tæb/	40	/tɛb/	0
cement	/sɛm/	60	/sɔm/	0
pollution	/pɔl/	100	/pæl/	0
divan	/dɪv/	40	/dɛv/	60
geranium	/dʒɛr/	100	/dʒɪr/	100
peculiar	/pɛk/	40	/pæk/	0
meticulous	/mɛt/	40	/mɪt/	60

The following are the items used in Experiment 2 along with the response time in milliseconds for each item.

Target	*B condition word*	*NB condition word*
/pʌd/	puddle 673	pudgy 852
/vɪn/	vinegar 986	vindicate 968
/gɔs/	gossip 580	gospel 813
/bæs/	basalt 829	bastion 889
/vɛn/	venom 823	venture 798
/sɪm/	similar 983	simple 935
/hɛk/	heckle 770	hectic 698

/kæl/	calibre 969	calculation 1043
/fɪk/	fickle 701	fictitious 1011
/tæl/	tally 855	talcum 771
/vɛs/	vessel 660	vestige 695
/fɪd/	fiddle 894	fidget 1062
/pɔs/	possum 764	posture 745
/mɪn/	minister 821	minstrel 1040
/æŋk/	anchor 580	anxious 702
/ɔ:t/	autopsy 1051	orchard 805
/vɔl/	volatile 738	voltage 763
/gʌs/	gusset 678	gusto 825
/sʌl/	sullen 925	sulky 1134
/vɪ:/	vehicle 855	veto 960

Word	*"Consistent" Target*		*"Inconsistent" Target*	
whistle	/wɪst/	1268	/wɪsk/	835
father	/fæs/	998	/fɔs/	1020
bullet	/bʌl/	981	/bɔl/	837
travel	/treɪv/	953	/trʌv/	989
humorous	/hʌm/	984	/hɔm/	809
passionate	/pæs/	1278	/pæt/	1026
lotion	/loʊt/	1170	/loʊs/	988
later	/læt/	970	/loʊt/	876
savoury	/sæv/	1205	/sɛv/	1239
demon	/dɛm/	984	/dɪm/	799
bargain	/bær/	1093	/bɔr/	980
honour	/hɔn/	921	/wɔn/	889
stomach	/stɔm/	1128	/stæm/	883
honey	/hɔn/	900	/hæn/	780
fever	/fɛv/	814	/fɪv/	1034
women	/wɔm/	1046	/wʌm/	1030
leather	/lɪ:θ/	833	/leɪθ/	826
basket	/bæs/	1175	/bɔs/	803
hotel	/hɔt/	1358	/hʌt/	1139
colour	/kɔl/	1077	/kɛl/	810

Target	*HF condition word*	*LF condition word*
/sɛn/	sentence 814	sentry 906
/fɔl/	follow 846	follicle 808
/sɛv/	several 864	sever 933
/dʒɛn/	general 680	genocide 976
/væl/	valuable 857	valentine 1014
/tɛr/	terrible 935	terrify 1014
/oʊ/	ocean 761	opal 849
/træv/	travel 568	travesty 906
/bæl/	balance 660	ballad 735
/bju:/	beauty 765	bugle 934
/æp/	apple 699	apathy 768
/vɔl/	volume 795	voluble 1056
/peɪp/	paper 605	papal 811
/kʌr/	courage 745	curry 885
/kʌl/	colour 729	culinary 864
/rɪ:dʒ/	region 711	regent 797
/saɪl/	silence 1087	silo 978
/kwɔ:/	quarter 815	quartet 925
/pær/	paragraph 930	parable 821
/kær/	character 899	caramel 819

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