JOURNAL OF MEMORY AND LANGUAGE **38,** 203–224 (1998)
ARTICLE NO. ML972538

Lack of Phonological Mediation in a Semantic Categorization Task

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This study addresses the question of whether it is possible to read a word for meaning without phonological mediation. The task was semantic categorization. Participants decided whether or not each target word belonged to the category ''words with definable meanings'' (e.g., PLANK, PINT) or the category ''given names'' (e.g., TRENT, PAM). To test phonological mediation, latencies to respond to regular definable words (e.g., PLANK) and irregular definable words (e.g. PINT) were compared. No regularity effect was observed, despite these same words showing a difference in a naming task. Thus the semantic task was shown to be insensitive to a phonological effect. The possibility that the long response times of the semantic categorization task washed out any regularity effect was dismissed on the grounds that both a word frequency effect and a letter transposition effect (e.g., CLUE vs CALM, cf. CLAM) were observed using this task. It is concluded that phonological mediation is not a prerequisite for semantic access.

Key Words: letter transposition; lexical processing; orthographic processing; phonological mediation; phonological recoding; semantic categorization; semantic processing; silent reading.

In order to read successfully, a lexical processing system is needed that contains information about the orthography, phonology and semantics of the words encountered. The orthographic information provides an entry into the lexical processing system in the sense that the incoming visual information is congruent with it. The phonological information is necessary if the word is to be read aloud (named), while the semantic information supplies the meaning of the word. In silent reading, it is logically possible for phonological information to be by-passed altogether so that when the stimulus activates orthographic information, the only other activation is of the semantic information associated with it. We will call this the O → S route to meaning.

An O → P pathway (orthography-to-phonology) must exist for the purposes of pronouncing the word, but it need not be involved in the activation of meaning. However, because a P → S pathway must also exist so that the meaning of spoken words can be accessed, it would be possible to go from orthography to semantics indirectly via phonology, that is, via an O → P → S route. In recent times, a case has been made for the idea that not only is the O → P → S route engaged when reading for meaning, but that it is actually the fundamental pathway to meaning, that is, phonology plays a crucial role in accessing the meaning of a word (e.g., Lesch & Pollatsek, 1993; Lukatela, Lukatela, & Turvey, 1993; Lukatela & Turvey, 1994; Peter & Turvey, 1994; Van Orden, 1987, 1990; Van Orden, Johnston, & Hale, 1988).

When it comes to considering the role of phonology in reading, there are actually (at least) three issues that need to be considered. The first is the issue that we will call ''phonological recoding'', which is whether a visually presented word is converted into its phonological form on the basis of sublexical information (by converting graphemic units smaller than the word into their corresponding phonemic units), so that lexical memory can be accessed via the P component without passing through the representation of the word in the O component. The second issue is whether phonology is automatically activated in the

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0749-596X/98 $25.00

course of silent reading, regardless of whether this phonology is activated via sublexical information or via an O → P route. However, even if the phonology of a word is automatically activated during silent reading, this does not mean that it is necessary to get to meaning via the P component. It is still quite possible that the O → S route to meaning exists as well, and even that it is the dominant route to meaning. Indeed, it may be the case that the primary function of phonological activation in silent reading is to enable the word to be held in working memory while its context is processed further (e.g., Baddeley, Eldridge, & Lewis, 1981; Kleiman, 1975) rather than as an access route to meaning. This third issue of whether the O → P → S route is dominant over the O → S route will be called ‘‘phonological mediation’’ and is the focus of the present study.

The three issues described above have often been conflated in the literature, but it is important to consider them separately because they are quite independent of each other, as will now be made clear.

PHONOLOGICAL RECODING

The issue of phonological recoding was extensively explored during the 1970s and early 1980s (see, for example, McCusker, Hillinger, & Bias, 1981), and was particularly inspired by the finding of a pseudohomophone effect using the lexical decision task (e.g., Besner & Davelaar, 1983; M.Coltheart, Davelaar, Jonasson, & Besner, 1977; Rubenstein, Lewis, & Rubenstein, 1971) whereby nonwords which are homophonic with a real word (e.g., LEEF) take longer to classify as nonwords than control items (e.g., SEEF). This suggested that the visual stimulus is converted into its phonological form prior to accessing lexical memory. Such ‘‘pre-lexical’’ recoding requires the existence of a set of grapheme-to-phoneme conversion (GPC) rules (e.g., P → /p/, I → /ɪ/) which will provide the phonology of the letter-string without access to lexical information. Not all words follow such rules, however, and therefore lexical information about phonology must be accessed in order to pronounce these irregular words. For example, PINT would be pronounced /pɪnt/ (as in MINT) if GPC rules were followed, in which case the correct pronunciation /paɪnt/ can only be known from stored information about that word (i.e., lexical information). Thus, M.Coltheart et al. (1977) proposed a dual-route model (see also M.Coltheart, Curtis, Atkins & Haller, 1993) whereby phonology is generated both pre-lexically (for nonwords and regular words) and lexically (for irregular as well as regular words). Note that the lexical route to phonology is exactly equivalent to the O → P route since it activates the phonological representation associated with an orthographic representation.

The question of whether the phonology of a real word is activated via the O → P route or via a set of sublexical conversion rules (e.g., GPC rules) has been primarily tested using a naming task which taps directly into the P component. The latency to initiate the pronunciation of a given letter-string is measured and it is well-established that irregular words (like PINT) are associated with longer latencies than regular words (like PLANK), particularly when they are of low frequency (Andrews, 1982; Baron & Strawson, 1976; Seidenberg, Waters, Barnes, & Tanenhaus, 1984; Stanovich & Bauer, 1978). This result has been taken as support for the dual-route model (e.g., M. Coltheart et al., 1977, 1993), because the pre-lexical and lexical routes both provide the correct pronunciation for regular words, but are in conflict for irregular words thus lengthening the naming latencies.

Alternatively, however, single-route connectionist accounts (e.g., Plaut, McClelland, Seidenberg, & Patterson, 1996; Seidenberg & McClelland, 1989) explain regularity effects in terms of competition between units which share orthographic structure but differ on phonological structure. That is, PINT suffers competition from MINT, HINT, etc, whereas the words that are of similar orthographic structure to PLANK all have compatible pronunciations (e.g., THANK, RANK, etc). By this account, it is not really ‘‘regularity’’ per se that is relevant, but rather, the proportion of

compatibly pronounced words to incompatibly pronounced words of similar orthographic structure (what Jared, McRae, & Seidenberg, 1990, call the ''friends/enemies'' ratio). The connectionist account, then, explains the difference between regular and irregular words entirely within the O → P component of the system.

AUTOMATIC PHONOLOGICAL ACTIVATION

Regardless of which explanation for the regularity effect is correct, there is the second issue of whether activation of phonology automatically occurs even when the P component is not explicitly required. One result that might appear to speak to this question is the difficulty in finding a difference between regular and irregular words in the lexical decision task which does not require the word to be named (e.g., Andrews, 1982; M.Coltheart, Besner, Jonasson, & Davelaar, 1979; Seidenberg, et al., 1984). In this task, words must be discriminated from nonwords, and the lack of a regularity effect suggests that phonology need not be involved in performing this task and is therefore not automatically activated in silent reading.

However, it is possible that phonology has indeed been activated by the visual stimulus, but that any problems in generating the correct pronunciation for an irregular word has no impact on lexical decision performance because the task is being performed purely on the basis of O information. That is, the lexical decision task can logically be performed on the basis of orthographic information alone, so that whether or not there is P information being activated at the same time can be disregarded when performing the task.

In fact, other experiments have provided evidence that automatic phonological activation does take place (e.g., Ferrand & Grainger, 1992, 1994; Grainger & Ferrand, 1994; Perfetti, Bell, & Delaney 1988). Most impressive perhaps is the study by Ziegler, Van Orden and Jacobs (1997) using a letter search task that could logically be carried out on a purely visual basis, yet finding an effect which is

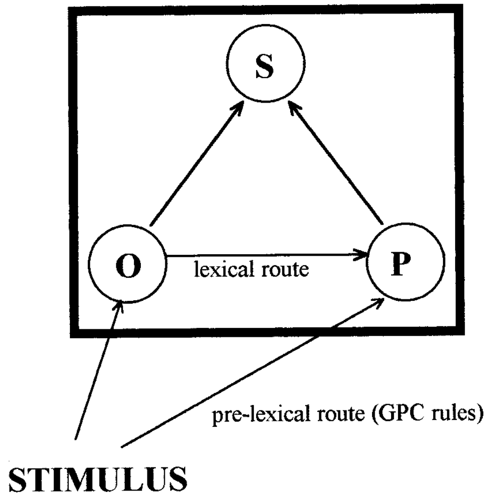

FIG. 1. Schematic representation of the lexical processing system with pathways from orthographic information (O) to both phonological information (P) and semantic information (S). The P component can be reached either via GPC rule conversion or directly from the O component.

mediated by phonology. For example, it was harder to say that the letter ''I'' appeared in the visually presented word HAIL than it was to say the same for the word NAIL. It was concluded that the homophone of HAIL which does not include an ''I'' (namely, HALE), was activated via its phonological representation while performing this task. The fact that such activation only serves to inhibit performance implies that it cannot be avoided and is therefore automatic.

This conclusion, however, merely says that activation of the P component is automatic and does not say anything about whether the phonology of a word is accessed via sublexical rules or directly from the O component. Furthermore, it does not imply that phonology is necessary for meaning to be accessed.

CONCEPTUALIZING THE LEXICAL PROCESSING SYSTEM

Fig. 1 makes it clear how phonological mediation can be seen as an independent issue to phonological recoding and automatic phonological activation. The figure presents a dia-

grammatic representation of the relevant pathways of the O-P-S system with a GPC route included (cf. M.Coltheart et al., 1977, 1993), and depicts the situation where it is possible to go directly from orthography to semantics (O → S) as well as via phonology (O → P → S). The issue at stake here is the importance of the former route relative to the latter route, and it can be seen that resolution of this issue is independent of whether or not there exists a GPC route to phonology. Moreover, if it is shown that the P component is automatically activated in silent reading, this does not imply that O → P → S is the only pathway to meaning. It may be the case that the direct O → S route is automatically activated at the same time, or even in advance of the phonologically mediated route.

The assumption of the sort of model found in Fig. 1 is that the O and P components represent the whole word and that any sublexical processing makes use of rules that act directly upon the visual stimulus (or at least, the sensory representation of it). The alternative possibility, though, is that sublexical information is an inherent part of the O and P components. Versions of this idea can be found in models like those of Grainger and Ferrand (1994), Plaut et al. (1996), Taft (1991), and Van Orden and Goldinger (1994). An example of how one might conceptualize this can be seen in Fig. 2 where the word CAT is used to illustrate the nature of the O and P representations.

In this localized connectionist framework, it can be seen that the O component and P component are composed of a hierarchy of units ranging from graphemes (e.g., C, A, and T) and phonemes (e.g., /k/, /æ/, and /t/) up to whole words. Activation passes up this hierarchy as well as between O and P units at the same level. The interface with semantics is only at the top of the hierarchy, namely, at the whole word level. In a framework such as this, automatic phonological activation necessitates sublexical activation because the links between orthography and phonology exist at all levels. So, if one considers the issues in terms of this framework, the question of automaticity and sublexical processing can be con-

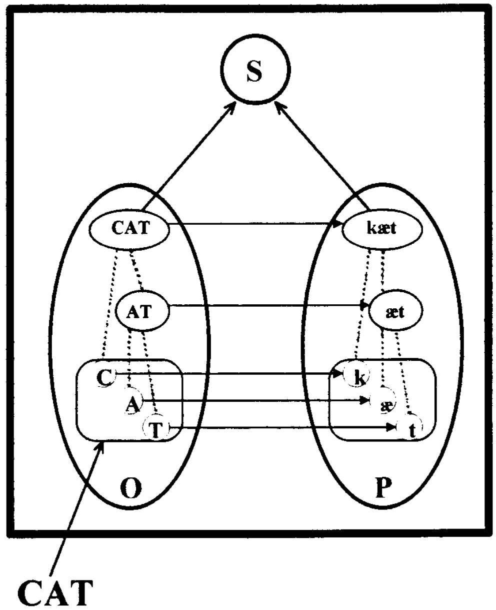

FIG. 2. Schematic representation of the lexical processing system with pathways from orthographic information (O) to both phonological information (P) and semantic information (S), where the O and P components are composed of a hierarchy of levels. The example of CAT is given to illustrate the units of representation.

sidered together. However, even in this account, automatic phonological activation does not preclude the use of a direct route from orthography to semantics. It merely says that the P component becomes activated in the course of silent reading and not necessarily that it is the dominant pathway to meaning.

PHONOLOGICAL MEDIATION

There have been a number of studies reported in the literature, however, that purport to demonstrate the importance of the O → P → S route. Several different paradigms have been used whereby semantics is either required by the task or shown to be involved in the task. Almost all of the studies tap into phonology in the same way, namely, via the manipulation of homophony. Examples of the different paradigms are now presented.

Eye Movements in Reading for Meaning

A number of studies have been carried out which examine the impact of homophony on

eye movements and fixations during the reading of a passage for meaning. This is achieved by having a word previewed by its homophone (e.g., Pollatsek, Lesch, Morris, & Rayner, 1992; Rayner, Sereno, Lesch, & Pollatsek, 1995) or by replacing a word in the passage with its homophonic partner (e.g., Daneman & Reingold, 1993; Daneman, Reingold, & Davidson, 1995; Rayner, Pollatsek, & Binder, 1998). These studies found different patterns of eye movements when homophones were involved (e.g., BEECH being homophonic with the appropriate word BEACH) in contrast to visual controls (e.g., BENCH being visually similar to BEACH). However, there is controversy as to the locus of this phonological effect with some suggesting an involvement early in processing (e.g., Pollatsek et al., 1992; Rayner et al., 1995, 1998) and others proposing that it only comes into play after meaning has been accessed (e.g., Daneman & Reingold, 1993; Daneman et al., 1995).

In perhaps the only reported study that examined phonological mediation without manipulating homophony, Inhoff and Topolski (1994) found that the duration of first fixations was longer for low frequency irregular words than low frequency regular words when embedded in a passage that was being read for meaning. However, this difference was as likely to have been a word frequency effect as a regularity effect because the irregular words were less frequent than the regular words (with mean frequencies of 18 and 38 per million respectively).

Semantic Categorization

Another approach to the issue has been to look at false alarms within a semantic categorization task. Banks, Oka, and Shugarman (1981), V. Coltheart, Patterson, and Leahy (1994), Peter and Turvey (1994), Van Orden (1987), and Van Orden, Johnston, and Hale (1988) all demonstrated a higher false alarm rate to homophones of category members than to orthographically similar controls. Thus, more errors were made in saying that LOOT (homophonic with LUTE) was not AN ANCIENT MUSICAL INSTRUMENT than to say the same of LOST. Because it was possible that such precise semantic categories allowed the target word to be generated prior to its presentation, Jared and Seidenberg (1991) used much broader categories (LIVING THING versus OBJECT) and still observed a higher false alarm rate with homophones, though only when they were of low frequency.

Sentence Acceptability

A related approach to the issue has been an examination of the judgment of sentence acceptability when one of the words in the sentence is a homophone of the appropriate word (e.g., Banks et al., 1981; Baron, 1973; V.Coltheart, Avons, Masterson, & Laxon, 1991; V.Coltheart, Laxon, Rickard, & Elton, 1988; Treiman , Freyd, & Baron, 1983). For example, SHE HAS BLOND HARE is harder to classify as an unacceptable sentence than is SHE HAS BLOND HARM. This task is equivalent to the semantic categorization task except that the decision to be made about the target word is whether or not it fits into a sentence context rather than into a semantically defined category.

Semantic Discrimination

Luo (1996) presented readers with three words and the task was to decide which of the first two words was semantically related to the third (e.g., LION related to WOLF). The word that was not semantically related was either homophonic with a semantically related word (e.g., BARE) or was merely visually similar (e.g., BEAN). The presence of the homophonic distractor made responses more difficult suggesting the involvement of phonological processing in this semantic task.

Semantic Priming

Another paradigm that has been used examines the semantic priming effect whereby responses to a target word are facilitated by the immediately prior presentation of a semantically related word. Lesch and Pollatsek (1993), Lukatela, Lukatela, and Turvey (1993), and Lukatela and Turvey (1994) demonstrated that naming times to a target word could be facili-

tated to the same extent when the prime was homophonic with a semantically related word (e.g., SALE priming BOAT) as when it was the semantically related word itself (e.g., SAIL priming BOAT). So, it appears that the semantic information that participates in the priming effect is generated from the pronounced version of the prime rather than from its orthographic representation.

The strongest position implied by these studies of homophony is that the only route from orthography to meaning is via phonological mediation (i.e., an O → P → S route) or at least that this is the dominant route. Such is the view adopted by Van Orden and his colleagues, Lukatela and Turvey and their colleagues, as well as Lesch and Pollatsek.

The alternative view is that the direct O → S route has an important role to play, which is the position adopted by Jared and Seidenberg, as well as by Fleming (1993). They observed a homophone semantic priming effect in a lexical decision task, but one that was weaker than the pure semantic priming effect. According to this account, semantic information can be retrieved directly from orthographic information, though phonology will come into play if the O → P → S processing can be completed before or at the same time as the O → S processing.

We see then that the level of involvement of phonological mediation in reading for meaning has hinged upon the degree to which a letter-string behaves like its homophonic partner. However, even though the tasks described above involve semantic processing, the fact that homophony has an impact still does not necessitate that O → P → S processing takes priority over O → S processing. Referring to Fig. 2, when a word is visually presented, the early sublexical orthographic processing starts to activate phonological sublexical units while passing activation up to the whole word level. Thus, activation of the phonological representation of the whole word will occur not long after activation of the orthographic representation of the whole word, as the former receives activation not just from the latter, but also from sublexical phonological activation. These whole word representations, once activated, will start to activate their associated semantic units. When the word being processed has a homophonic partner, it is possible for two sets of semantic units to be activated via the phonological representation and therefore confusion can occur. However, this does not preclude the possibility that the orthographic representation is also activating semantic units at much the same time or even earlier, and if it succeeds more quickly than does the phonological activation, there will be no effect of phonology.

One way to test such a ‘‘horse-race’’ account, is to look at a situation where sublexical processing does not provide any support to the phonological activation. In such a situation, the capacity of the O component to activate the P component will be no greater than its capacity to activate the S component and, therefore, it would be likely that the O → S route will reach its goal before the O → P → S route because it simply involves one less pathway. This is the case in Chinese (and Japanese Kanji) where the only systematic relationship between orthography and phonology is at the character (morpheme) level and not at the sublexical level. In accordance with the horse-race account, the homophone effects reported in the semantic categorization and semantic priming tasks with English are difficult to obtain with Chinese and Kanji.

Wydell, Patterson, and Humphreys (1993) failed to find an inflated false alarm rate in the semantic categorization task with Kanji homophones when the members of a homophonic pair shared no orthographic components, and Leck, Weekes, and M.J. Chen (1995) and H.-C. Chen, Flores D'Arcais and Cheung (1995) reported the same thing in Chinese. In addition, Tan and Perfetti (1997) found that semantic priming with homophones in Chinese was less effective than normal semantic priming, while Zhou (in press) failed to find any facilitation at all from homophonic semantic primes.

The conclusion drawn from the research on non-alphabetic script has been that phonology may be automatically activated in reading for

meaning (see also Flores D'Arcais, Saito, & Kawakami, 1995; Perfetti & Zhang, 1991, 1995; Tan, Hoosain, & Peng, 1995; Tan, Hoosain, & Siok, 1996), but that it is also possible to go directly from orthography to semantics. Indeed, the lack of homophone effects suggests that the direct access of semantics from orthography takes priority when sublexical O-P associations are not available to facilitate the activation of the P component. It could be argued, though, that the O → S option is available to readers of non-alphabetic scripts only, given the arbitrariness of the O-P associations. What is needed is direct evidence from an alphabetic script and the present study seeks to provide this.

AN ALTERNATIVE TO HOMOPHONY MANIPULATION

The present research makes use of the semantic categorization task because it is a task that taps directly into the S component. The finding of phonological effects in the semantically primed naming task (e.g., SALE priming BOAT) does not necessarily address the issue of phonological mediation, despite the assumptions of those who use it (e.g., Lukatela et al., 1993; Lukatela and Turvey, 1994). The same results would be found even if the O → S route typically wins the race against the O → P → S route. When SALE is presented, the O → S route will activate its meaning, while the O → P → S route will, a short time later, allow the ''boat'' meaning of /seɪl/ to be accessed as well. When BOAT is then presented as the target, the pre-activated semantic information about ''boat'' can be accessed via the O → S route. It would then be via an S → P link that exists for the purposes of pronouncing self-generated words, that naming responses to the target would be facilitated. Thus, it could be argued that the semantically primed naming task addresses the question of semantically mediated phonological activation (i.e., O → S → P) as much as it addresses the question of phonologically mediated semantic activation (i.e., O → P → S) and that is why the semantic categorization task is preferred here.

However, the use of homophony as the measure of phonological involvement in the semantic categorization task optimizes the likelihood that the use of the O → P → S route will be detected. This is because during the period that it takes to decide whether a target belongs to the category, there is time for the O → P → S route to come into play such that the inappropriate meaning can be activated and conflict with the meaning activated via the O → S route. Rather than looking at a situation where the O → P → S and O → S routes are in conflict, the present study manipulates the time taken to complete the O → P stage of the O → P → S route. This is achieved by comparing regular and irregular words (e.g., PLANK versus PINT) where the phonology of the latter takes longer to generate than that of the former, as gauged in a naming task (e.g., Andrews, 1982; Baron & Strawson, 1976; Seidenberg, Waters, Barnes, & Tanenhaus, 1984; Stanovich & Bauer, 1978).

Although there may be a delay in accessing the phonology of an irregular word, there would be no conflict in a semantic categorization task between the output of the O → P → S and O → S routes. That is, PINT will eventually activate the representation for /paɪnt/ which, in turn, will activate the correct meaning which is the same meaning as that activated directly from the orthographic representation for PINT. Now, if the semantic judgement can always be based on the O → S route, with a contribution from the O → P → S route if it is fast enough, then any delay in using the O → P pathway will be irrelevant. Even if the meaning of an irregular word has been accessed before the orthographically based response is made, there will be no conflict between the S representations accessed via the two pathways and, therefore, no delay in responses.

The present study, then, examines whether there is a regularity effect in the semantic categorization task. Regardless of the particular model that is adopted (Fig. 1 or Fig. 2), the important point for the study to be reported here is that the regularity effect observed in the naming task arises from the conversion of

orthographic information into phonological information. Thus the naming task taps directly into the P component of the system. What this means is that one can determine if the P component is involved in semantic processing by examining whether an effect that shows up in the naming task also shows up in a task that taps directly into the S component. In other words, if semantics is primarily accessed via phonological mediation (i.e., via an O → P → S route) then the regularity effect (arising from O → P) should be revealed in a semantic categorization task. On the other hand, if the direct route from orthography to semantics is as least as important as the phonologically mediated route, there will be no regularity effect in the semantic categorization task.

EXPERIMENT 1

The first step in determining whether there is a regularity effect in semantic categorization is to set up a set of items which clearly show a regularity effect in the naming task. Such was the function of Experiment 1.

Method

Participants. The participants were 16 undergraduate students at the University of New South Wales. Most were first year psychology students who received course credit for their participation. English was the first language of all participants.

Materials. The test stimuli were 20 regular and 20 irregular nouns and verbs defined according to two main selection criteria. The regular words had a high friends/enemies ratio (more friends than enemies), and had pronunciations predicted by the grapheme-phoneme correspondences described by Venezky (1970). The irregular words had a low friends/enemies ratio (more enemies than friends) and had pronunciations discrepant from those predicted by Venezky's grapheme-phoneme correspondences. None of the words chosen were 'strange' words. That is, the spelling patterns of irregular words were not unique or extremely uncommon (such as YACHT or WALTZ), since Waters and Seidenberg (1985) suggested that 'strange' words confound regularity of spelling with regularity of pronunciation. (See the appendix for the list of regular and irregular words).

The regular and irregular words were matched pairwise according to word frequency and initial phoneme, as well as approximate length. Matching according to initial phoneme was necessary since the voice-key which was used to record verbal reaction times was differentially triggered by different phonemes. All words were six or fewer letters in length and of one syllable duration. They were all classified as low to medium frequency with overall frequency ranging from rates of occurrence of 0.47 per million to 37.4 per million according to Carroll, Davies, and Richman (1971). The mean frequency of the regular words was 9.3 and the irregular words 9.2.

Procedure. Items were presented one at a time as white, uppercase characters on a black background. Each word appeared in the center of the screen and remained visible for 500 ms. Participants were instructed to pronounce each presented word as quickly but as accurately and as distinctly as possible. A voice-key was placed directly in front of the screen and approximately 5cm from the participant's mouth. Instructions stated that participants should not touch the voice-key and should verbalize only when responding to the stimulus.

Participants controlled the onset of both the practice sequence and the subsequent test sequence by pressing a button labelled ''Start''. The first two words of the test sequence were filler items, followed by the 40 regular and irregular words. The ten practice items and the two initial filler items in the test sequence were presented in the same order to all participants, while the test items were presented in a different random order to each participant.

The experimenter listened to responses via headphones in an adjoining room to determine the accuracy of pronunciation. A response was considered incorrect if it was not a known pronunciation of that word or if participants hesitated while naming the word. The reaction times of incorrect pronunciations were excluded from analysis. If a response was not

TABLE 1

Naming Times (in Milliseconds) and Percentage Error Rates for the Irregular and Regular Words of Experiment 1, with Standard Deviations in Parentheses

Examples:	Irregular PINT, BROOCH	Regular PLANK, BRINE
Reaction time	511 (52)	493 (39)
Error rate	5.3% (8.9)	1.3% (2.6)

made within 5 seconds from the stimulus onset an incorrect response was automatically recorded and the next stimulus presented. This only happened if responses were not loud enough to trigger the voice key, which occurred on approximately 1% of the total number of responses.

Results

Responses faster than 200 ms and slower than 2000 ms were eliminated from the analysis as it was assumed that these were too fast and too slow respectively to reflect typical processing of the stimulus.

The naming latencies and error rates for the irregular and regular words are found in Table 1.

The 18 ms difference between regular and irregular words was significant, $F_1(1,15) = 8.61$, $p < .01$; $F_2(1,19) = 8.91$, $p < .01$, as was the 4% difference in error rate, $F_1(1,15) = 14.70$, $p < .01$; $F_2(1,19) = 4.52$, $p < .05$.

Discussion

It was easier to name the regular words than the irregular words, indicating that this set of items was adequately designed to reveal the functioning of the O → P route in the naming task. According to the dual-route account (Fig. 1), the regularity effect arises from the conflict between the O → P and GPC routes to phonology. Within the hierarchical connectionist framework of Fig. 2, the effect arises from the fact that inconsistencies in the sublexical phonology will generate conflict. For example, the orthographic unit INT will activate the phonological units of both /ɪnt/ and /aɪnt/ with the latter ''irregular'' form providing weaker activation than the former because it is less common (having fewer friends than enemies).

The same set of items was used in Experiment 2 using a semantic categorization task in order to determine whether the same phonological effects occur when only the meaning of the printed word is required.

EXPERIMENT 2

In Experiment 2, a task was used where it was necessary to go beyond the orthographic component of the lexical processing system, but where phonology was not explicitly required. The task was semantic categorization whereby participants are given a category and must decide whether a subsequently presented word belongs to that category or not. Among the words used here were the 20 regular and irregular word pairs which had exhibited sensitivity to phonological recoding in Experiment 1.

The existence of a regularity effect is a diagnostic for the use of the O → P route regardless of whether the effect is explained within the framework of a dual-route (Fig. 1) or hierarchical connectionist (Fig. 2) model. Therefore, if semantics is accessed via the O → P route, the regularity effect should be evident in the semantic categorization task. If, on the other hand, semantic access can proceed directly from the orthographic representation (i.e., O → S), then a regularity effect should not be obtained.

When Van Orden (1987, Van Orden et al., 1988) used the semantic categorization task to tap into phonological processes, the categories were changed from item to item and many had a very small numbers of exemplars (e.g., AN ANCIENT MUSICAL INSTRUMENT, PART OF A HORSE'S HARNESS). Jared and Seidenberg (1991) argued that such small categories may allow activation of all known members of the category prior to presentation of the target word. These preactivated exemplars may well be phonologically maintained. The target word might then be translated into phonology for comparison with this preacti-

vated list. Thus phonological effects such as homophony would be observed, but the semantic representation of the target word would not have been accessed at all. In light of this criticism, the semantic categories in the present study were much larger than those used by Van Orden.

In addition, rather than inserting a different category label before the presentation of each target word, only two categories were used so that the same binary decision could be made for each item. Such an approach was also used by Monsell, Doyle, and Haggard (1989) with the categories ANIMATE versus NON-ANIMATE, Forster and Shen (1996) with the categories ANIMAL versus NON-ANIMAL, and Forster (1985) with BIGGER THAN A BRICK versus SMALLER THAN A BRICK.

Now, despite the reputation of English as having a highly irregular spelling system, it is actually quite difficult to find a large number of irregular monosyllabic words that can be clearly defined as ''animate'', ''inanimate'', or ''having a specific size''. Therefore, it was necessary to find an even less restrictive category than these. To this end, the categories that were selected were HAVING A DEFINABLE MEANING versus A GIVEN NAME. The former category allowed a response to be made to any normally used word, though only nouns and verbs were selected because, unlike given names, a noun or verb has a clearly definable meaning. ''Given names'' are merely labels which are arbitrarily applied, and as such, do not have universally definable meanings. For example, the features of a GLOVE are able to be described and, therefore, the word should be classified as having a definable meaning, whereas there are no features common to every TRENT and, therefore, TRENT should be classified as not having a definable meaning. The only way to distinguish GLOVE from TRENT in terms of the definability of their meaning is to go beyond their orthographic representations and access their semantic representations (which in the case of TRENT would be ''a male name''). Of course, there are some words which fall into both categories (e.g., PEARL, BOB), but none of the test words in the present experiment were of this type.

There exists a potential problem in using semantic categorization as a task, however, and that is that more is being measured than mere access to meaning. An assignment to the appropriate category has also to be made on the basis of the semantic information so accessed. Variations in the ease of making this decision will add variability to the response times and error rates, and this is potentially a problem because randomly selected exemplars of a category will vary on their typicality of category membership (Wittgenstein, 1953). For example, ''sparrows'' and ''pigeons'' are more typical of the category BIRD than are ''peacocks'' and ''vultures'' (Medin and Shoben, 1988). Previous studies using the semantic categorization task have generally ignored this problem, but it has the potential to contaminate results. A genuine regularity effect might be obscured by these variations in typicality. The problem is tackled in two ways in the present study.

A category composed of all words with a definable meaning is so broad that effects of typicality of membership are unlikely to occur and, while a typicality effect may well arise for the given name category, this is unimportant because they are simply filler items. However, a type of typicality effect may influence responses to critical target words in the form of bias against a definable word if it has some potential for being a given name, even if only as a nickname. For example, the words BRIDE and WORM may be thought to be more like a given name than are SCALP and WOOL, and may therefore elicit comparatively longer response times or more errors in categorization regardless of the lexical processes involved. To control for this possible confound, after completion of the semantic categorization task, all of the target words were rated for their ''likelihood of being used as a given name'' in order to determine whether this factor could account for the results obtained.

The second way in which an attempt was made to establish whether the semantic cate-

gorization task was sensitive to any effects generated during the accessing of lexical information was to include a manipulation of word frequency in the experiment. The logic behind this was that if a frequency effect is observed in the experiment, it means that the task was sensitive to the effects of basic lexical processing. The same logic was used by Monsell et al. (1989) and Forster and Shen (1996) who were both able to show a frequency effect in a semantic categorization experiment where the categories were large.

The question of the existence of a frequency effect is independent of whether or not the O → P route is involved in the task. Although it is possible for the frequency effect to arise from within the O → P route (as suggested by McCann & Besner, 1987, and McCann, Besner & Davelaar, 1988), this is unlikely to be the only source. The most frequently ascribed locus for the frequency effect is in the retrieval of the orthographic representation itself (e.g., Forster & Chambers, 1973; Fredriksen & Kroll, 1976; Monsell et al., 1989; Taft & Russell, 1992), though it could also arise from within an O → S route (if one exists). Thus, a frequency effect should be observed in the semantic categorization task even if phonological mediation is not involved in word comprehension.

To summarize the main hypothesis of Experiment 2, it was reasoned that if phonological recoding mediates the pathway from orthography to semantics in word comprehension then a regularity effect should be evident in the semantic categorization task. Conversely, absence of a regularity effect in semantic categorization could be due either to a lack of phonological mediation or a washout from task demands. The presence or absence of the frequency effect would indicate which of these explanations for the absence of a regularity effect was most likely.

Method

Participants. Twenty new participants were recruited from the same pool as Experiment 1.

Materials. The test stimuli were the 20 regular and 20 irregular low/medium frequency words from Experiment 1, as well as 15 regular high frequency words and 35 given names.

Like the low/medium frequency words, the 15 high frequency words were a maximum of six letters in length and one syllable in duration. They ranged in frequency from 157 to 467 words per million with a mean of 255. These high frequency words were all classified as regular according to Venezky (1970) as well as in terms of their friends/enemies ratio and, as such, were designed to be compared to the regular low/medium frequency words.

The 35 given names were male and female first names (e.g. TRENT, PAM, CHRIS, JANE), and were also a maximum of six letters in length and of one syllable duration. These names can be found in the Appendix.

Procedure. The items were displayed under exactly the same conditions as in Experiment 1. Importantly, each word was presented in upper case letters so that the definable words and given names could not be distinguished on the grounds that the given names began with a capital letter. Participants were instructed to decide for each word whether it had a definable meaning (that is, a noun or verb such as BELT or JUMP) or if it was simply used as a person’s given name, with no definable meaning of its own (e.g., CRAIG, GWEN). Responses were made by button press. Instructions to participants, as in Experiment 1, emphasised that responding should be as fast but as accurate as possible.

Like Experiment 1, a practice sequence preceded the test sequence, and the initial two items in the test sequence were fillers. These were items of similar structure to the test words. The 40 regular and irregular words, 15 high frequency words and 35 given names were presented in a different randomized order for each participant.

After the semantic categorization had been completed participants were given all of the test items on a piece of paper and asked to rate them on their typicality as a given name. A seven point Lickert scale was provided for word ratings, ranging from 1 = ‘‘very likely

TABLE 2

Semantic Categorization Times (in ms) and Percentage Error Rates for the Irregular, Regular and High Frequency Words of Experiment 2, with Standard Deviations in Parentheses

Examples:	Irregular low/medium frequency PINT, BROOCH	Regular low/medium frequency PLANK, BRINE	Regular high frequency SHIP, BLACK
Reaction time	616 (65)	623 (42)	562 (29)
Error rate	5.3% (5.5)	7.3% (8.5)	3.7% (4.0)

to be someone's given name'' to 7 = ''very unlikely to be someone's given name''.

Results

One participant was replaced because of an average error rate which exceeded 20% and, as in Experiment 1, reaction times greater than 2000 ms and less than 200 ms were excluded from the analysis.

Table 2 presents the means and error rates for the irregular and regular (low/medium frequency) conditions and the high frequency words.

It can be seen from the means that, if anything, the irregular words were easier to categorize as a definable word than were the regular words, though this was far from significant in both the analysis of reaction time and errors, all Fs < 1.

The reaction time difference between the 15 high and the 20 low/medium frequency regular words, on the other hand, was highly significant, $F_1(1,19) = 23.17$, $p < .001$; $F_2(1,33) = 22.46$, $p < .001$, while the error difference reached significance on the participant analysis only, $F_1(1,19) = 4.44$, $p < .05$; $F_2(1,33) = 2.27$, $p > .05$.

The ratings for the likelihood of being a given name were found to be well-matched between the conditions, with a mean of 6.6 (standard deviation = .27) for the irregular words, 6.8 (sd = .19) for the regular words and 6.7 (sd = .23) for the high frequency words. The ratings ranged from 5.3 to 7, so it can be seen that the definable words were thought to be very unlike any given name (remembering that a rating of 7 meant ''very unlikely to be a given name'').

Average response time to correctly respond to the given names was 604 ms with an error rate of 8%.

Discussion

No significant regularity effect was evident in the semantic categorization task. The reaction time and error rate differences, though nonsignificant, were in the opposite direction from usual regularity effects and stand in stark contrast to the significant regularity effect in both reaction time and error rate obtained in Experiment 1. The two conditions were closely matched on their mean ''likelihood of being a given name'' and, therefore, it seems that category confusibility was not a confounding factor in the experiment and the finding of a frequency effect in this experiment demonstrates that the task was capable of detecting effects that arise during lexical processing. The results, then, suggest that meaning can be accessed directly from the orthographic representation as opposed to the requirement of phonological mediation.

There are three potential counter-arguments to this conclusion, however. First, it could be argued that the discrimination of definable words from given names does not necessarily require access to the semantic component of the lexical processing system. Instead, it would be possible simply to address orthographic information stored in the O component of the system to establish whether the word takes an initial capital letter or not. In this way the response could be made without consulting the meaning of the word.

Whether or not this is what the participants did can be examined by looking at whether

responses to the definable words were affected by the rated likelihood of those words being a given name. If response times and error rates were slowed by a greater likelihood of the word being used as a given name, this could only be explained in terms of information found within the S component. For example, if WORM has some of the qualities of being a given name, that would be a result of its meaning and not because it has sometimes been encountered before as a given name with an initial capital letter (since it is not actually a given name). Correlational analyses were therefore carried out between the given-name ratings and the response times and error rates, partialing out the effects of word frequency. Although the success of this procedure was hampered by the fact that the words were rated within a very narrow range, the correlation for error rates was nonetheless significant ($r = 0.375$, $p < .02$) and the correlation for response times was marginally so ($r = 0.278$, $p < .1$). Thus it can be concluded that the S component was being accessed in performing the semantic categorization task.

A second possible alternative explanation for the results is that regularity effects only arise at the stage when the phonological representation is converted into its articulatory output. Such a view is advocated by Inhoff and Topolski (1994) and Frost (1998). Given that irregularity is defined in terms of the orthographic-phonological mapping, such a view requires a very different description of what is meant by a phonological representation. Frost suggests that the phonological representation is underspecified, particularly in relation to its vowels. Thus, PINT and MINT are represented by /p∂nt/ and /m∂nt/ respectively, where /∂/ is an indeterminate vowel that could range from /e/ to /ɪ/. The details of which vowel /∂/ represents for any particular word are only generated when pronunciation is required and, therefore, Frost claims that regularity effects will only emerge in a naming task and not in semantic categorization.

This proposal, however, would be unable to handle the homophone effects that have been obtained in the semantic categorization task. For example, V. Coltheart et al. (1994) found that DEAR was confused with its homophonic partner DEER to a greater degree than PEER was confused with its non-homophonic partner PEAR. According to Frost's logic, DEAR (regular) and PEAR (irregular) would have the same indeterminate vowel which, in turn, must be the same as that of DEER and PEER (since DEAR and DEER are homophonic). This means that if semantic categorization were based on a phonological representation with only an indeterminate vowel, PEER would be just as homophonic with PEAR as DEAR is with DEER and, therefore, should create just as much confusion.

A third counter-argument to the failure to find a regularity effect in semantic categorization is that task demands did indeed wash out the effect, but that the frequency effect was robust enough to overcome this. One good reason for proposing that frequency is a more robust effect than regularity is that the frequency effect might well arise in more than one stage of lexical processing, whereas the regularity effect logically arises only in O → P processing. Frequency effects most likely reside in orthographic recognition (Forster & Chambers, 1973; Fredriksen & Kroll, 1976; Monsell et al., 1989; Taft & Russell, 1992), but may also occur in other stages of lexical processing. For example McCann and Besner (1987) and McCann et al. (1988) suggested that frequency influences the process of translation between domains (e.g. O → P). While this claim has been argued against (Monsell et al., 1989) and suggested to be unnecessary for accounting for the empirical evidence of frequency effects (Taft & Russell, 1992), it remains a possibility.

Therefore, if one wished to maintain the view that the semantic categorization task was carried out via an O → P → S route, one could argue that frequency effects arise in getting to the O component, in using the O → P subroute and even in using the P → S subroute, whereas the regularity effect only arises in using the O → P subroute. Because frequency is an effect with a wider locus than regularity, it is

not washed out during semantic categorization while the less pervasive effect of regularity is.

Although Experiment 2 shows no evidence of a regularity effect that is too weak to be detected, and even shows a reverse effect, it is worth addressing this concern directly. To do this, it would be appropriate to manipulate another variable as a further test of the sensitivity of semantic categorization to lexical effects. In particular, this variable should only affect one stage of lexical processing and this stage should be one that is indisputably involved in getting from orthography to meaning, regardless of the route taken to do so. The only stage which fits this description is the accessing of the O component: Whether an O → S route or O → P → S route is used, the O component must always be accessed. A variable which logically only affects the accessing of the O component was therefore examined in Experiment 3.

EXPERIMENT 3

To determine whether semantic categorization washes out any lexical effect which emanates from a single source, a manipulation of transposed-letter (TL) confusability was used. TL words are those from which another real word can be made by reversing the order of two consecutive letters (eg. CALM/CLAM, CARVE/CRAVE, SANG/SNAG). Chambers (1979) found that lexical decision responses to TL words were slower than responses to non-transposable control words. Andrews (1996) subsequently found that the higher frequency member of a TL pair (e.g., CALM) was responded to more slowly than its control (e.g., CLUE) in both lexical decision and naming, and that the lower frequency member of the TL pair (e.g., CLAM) was named less accurately than its control (e.g., CLIP).

This effect must arise in the early stage of orthographic processing of the printed word representation. Andrews (1996) noted that the TL effect implies that the coding of letter position must be approximate as opposed to absolute. Furthermore, Chambers (1979) found little indication of effects of phonemic similarity on TL confusability, which supports the notion that TL effects arise purely in orthographic processing. Indeed, the two members of a TL pair are rarely very similar in terms of phonology (e.g., CLAM is phonologically quite different to CALM, i.e., /klæm/ versus /ka:m/, and CARVE is phonologically quite different to CRAVE, i.e., /ka:v/[1] versus /kreɪv/). Since orthographic processing is necessary for semantic access, the TL effect should be evident in semantic categorization, regardless of the presence or absence of phonological mediation.

Experiment 3 utilised the same semantic categorization task as Experiment 2, but instead of regularity, the list of critical target words were manipulated in terms of TL confusability. The TL and control words constituting this list were selected from the higher frequency TL words used by Andrews (1996) because the items in the two conditions were well-matched on word frequency and regularity. The reason for choosing the higher frequency items rather than the lower frequency ones was that the former exhibited a TL effect in both lexical decision and naming. Therefore, absence of a TL effect in semantic categorization using these words would have to be due to insensitivity of the task rather than the nature of the word list.

As in Experiment 2, ratings of ‘‘likelihood of being a given name’’ were collected in order to account for the possible confound of category typicality effects.

Method

Participants. A new group of 20 participants was recruited from the same undergraduate student population as in Experiments 1 and 2.

Materials. The words selected were twenty of the TL and control pairs of words used by Andrews (1996) in her high frequency list (see the Appendix for the items). Only the monosyllabic items used by Andrews were included. The TL words could all create a lower

[1] Australian pronunciation is being referred to because this is the dialect used here (as well as in the Chambers and Andrews studies).

TABLE 3

Semantic Categorization Times (in ms) and Percentage Error Rates for the Transposed Letter (TL) and Control Words of Experiment 3, with Standard Deviations in Parentheses

	TL	Control
Examples:	CALM, CARVE	CLUE, CORN
Reaction time	598 (34)	577 (33)
Error rate	2.8% (3.0)	1.3% (2.8)

frequency word when two adjacent letters were transposed (e.g., CALM, SANG, CARVE) whereas when two letters were transposed in the control words, an orthographically legal letter-string was created, but this was not a word (e.g., CLUE, SAIL, CORN; cf. CULE, SIAL, and CRON). The mean frequency according to Carroll et al. (1971) was 19.80 for the TL words and 19.14 for the controls. The given names were the same as those used in Experiment 2.

Procedure. The procedure was exactly the same as in Experiment 2.

Results

Two participants were replaced because of an average error rate which exceeded 20%. As in the other experiments, reaction times greater than 2000 ms and less than 200 ms were excluded from the analysis.

Table 3 presents the means and error rates for the TL and control words.

It can be seen from the table that TL words were categorized more slowly than their controls and this was a significant difference, $F_1(1,19) = 5.03$, $p < .05$; $F_2(1,19) = 4.80$, $p < .05$. There was no significant difference in accuracy, $F_1(1,19) = 1.69$, $p > .1$; $F_2(1,19) = 2.41$, $p > .1$.

The ratings for the likelihood of being a given name were again found to be well-matched between the conditions, with a mean of 6.6 (standard deviation = .51) for the TL words, and 6.8 (sd = .38) for the control words. The ratings ranged from 5.1 to 7.

Response times to the given names averaged 570 ms with an error rate of 6.3%.

Discussion

It is apparent that the semantic categorization task is not so variable that it washes out all effects arising from lexical processing apart from frequency. The task is certainly sensitive enough to pick up the effects of confusability between words that differ from each other in terms of transposable letters. This confusability effect logically arises only in the accessing of the orthographic representation of the word. When CALM is presented, the O representation for CLAM becomes activated along with the O representation for CALM, hence creating competition.

What this tells us is that the failure to find a regularity effect in the semantic categorization task is likely to be a genuine null result and this, in turn, implies that categorization can be made without any influence from the phonological component of the lexical processing system. It seems that phonological mediation between orthography and semantics is not obligatory.

GENERAL DISCUSSION

The three experiments reported in this paper combine to provide evidence against the notion that phonological recoding is necessarily involved in semantic access. Direct evidence for this conclusion was provided by Experiment 2, where a phonological effect (i.e., regularity) was not obtained in a task requiring semantic access (i.e., semantic categorization) despite the fact that Experiment 1 had revealed such an effect in a task requiring phonological access (i.e., naming). The effect of letter transposability demonstrated in Experiment 3, as well as the frequency effect obtained in Experiment 2, suggest that the semantic categorization task should have been sensitive enough to detect regularity effects if there were any.

Mediated and Non-mediated Semantic Access as Dual Routes

While we conclude that phonological mediation is not a necessary route to meaning, it seems

likely from previous research that phonology is nonetheless automatically activated in the presence of a visually presented word. Our results suggest, however, that this phonological activation merely serves to supplement the direct orthographic route to meaning such that variations in the ease of its use (i.e., reading regular versus irregular words) have no effect on access to meaning. The impact of the phonologically mediated route to meaning will be witnessed primarily when its output is rapid enough to produce conflict with the orthographic route, that is, when the stimulus is a letter-string that is homophonic with a semantically inappropriate word. As pointed out earlier, almost all evidence in favor of phonological mediation comes from an examination of homophony which, it is argued here, overstates the importance of the O → P → S route. When regularity (or friend/enemy ratio) is used as the measure of phonological involvement, there is no evidence that the O → P → S route takes priority over the O → S route.

Now, the obvious argument against this conclusion is that it is founded on a null effect. To handle this problem, we have tried to demonstrate that the task used was sensitive to other effects and that, therefore, it should have been capable of revealing a regularity effect if one were present. Furthermore, it was not the case that there was any hint of a tendency for irregular words to take longer than regular words in the semantic categorization task. In fact, the tendency was in the reverse direction. It is for this reason, we proffer a null effect as support for the importance of the O → S route.

Evidence for phonological mediation, in contrast, is always founded on positive results and this has convinced many of its overriding importance (e.g., Frost, 1997; Van Orden, Pennington, & Stone, 1990; Van Orden & Goldinger, 1994). Frost (1998) states that it is incumbent on those who support the importance of an O → S route to provide direct evidence for it, as has been done for the mediated route. However, it is actually very difficult to provide anything other than null effects as evidence of the O → S route: Any effects arising from a direct manipulation of either the O or S components can be equally explained in terms of O → P → S because that pathway also contains those components. It is straightforward to demonstrate the effects of a mediating variable, in this case the P component, but there is little that can be done to demonstrate the existence of a non-mediated route other than finding no effect of that mediating variable.

There is, however, one way of providing indirect, but positive evidence for an orthographic route to meaning and that is if it can be shown that semantic factors have an impact on the phonological component. This would provide evidence for O → S → P processing which necessitates the existence of an O → S pathway. Such evidence exists. While Perfetti and Zhang (1995) observed phonological interference in a semantic task (with homophony of two words disrupting synonym judgements), they also observed semantic interference in a phonological task (with synonymy disrupting homophony judgements). These results strongly suggest that both semantics and phonology are activated via orthography and that both outputs can interfere with each other if incompatible. The experiments of Perfetti and Zhang were carried out in Chinese where there is no sublexical support for the phonology of the words, and this optimizes the likelihood that the O → P pathway will be slow enough to allow effects of the O → S → P route to come into play. As mentioned earlier, however, it could be argued that an O → S route becomes important only in a logographic script, such as Chinese, where O-P links are arbitrary.

Nevertheless, evidence for O → S → P processing exists in English as well. The use of irregular words means that O → P activation is relatively slow and this gives an opportunity for the semantically mediated route to phonology (O → S → P) to come into play. Strain, Patterson and Seidenberg (1995) capitalized on this possibility by demonstrating that naming responses to irregular words are affected by the semantic variable of imageability. If naming were taking place purely on the basis of an O → P route,

there would be no reason for semantic characteristics of the word to influence response times. Thus it is implied that getting to the P component from the O component can sometimes be achieved more effectively via the semantically mediated route, namely, when sublexical information is unhelpful in generating the phonology of a word from its orthography, and this implies that the O → S route is automatically activated even when the response is directed at the P component.

The conclusion we wish to draw, then, is that there are two potential routes from orthography to meaning and that the non-mediated route is often the first to reach its goal as is witnessed by the lack of a regularity effect in the semantic categorization task. Such a dual-route model must be distinguished from the traditional dual-route model (e.g., M.Coltheart et al., 1977, 1979, 1993) in that the former involves a contrast between an O → S and O → P → S route while the latter involves a contrast between an O → P route and a GPC → P route.

While the idea of a dual-route model in relation to semantic access neatly combines the findings that support a non-mediated route with those that support a mediated route, it is actually possible to take a stronger position than this and claim that there is no O → P → S route at all. The arguments for this will now be presented. Such a position should be seen as being speculative at this stage, but because we believe it is a viable possibility, consideration must be given to it.

No Phonologically Mediated Route to Meaning in Silent Reading

In a framework such as that given in Fig. 2, phonology is automatically activated at sublexical levels via links with orthographic units and this sublexical activation feeds up to the lexical level (i.e., the whole-word level). Now, activation not only passes across from O units to P units, but can rebound back from P units to O units. Thus, while the orthographic unit EE will send activation to the phonological unit /i:/, the latter will send activation back to the EE unit as well as to the EA unit with which it is also linked. Such an idea was put forward by Taft (1991) and helps explain why Taft (1982) found that a nonword like STEEK was associated with longer lexical decision times than a nonword like FLEEK. Even though the pronunciations of these two nonwords are equally similar to a real word (STEAK and FLAKE respectively), in the former case, the EE → /i:/ → EA rebound will activate the orthographic unit for STEAK, but there is no link between /i:/ and A-E that will activate FLAKE from FLEEK. Similar notions have been put forward by Stone, Vanhoy, and Van Orden (1997).

Such O-P-O rebound (or ‘‘feedback phonology’’ as Stone et al. call it) explains why V.Coltheart et al. (1994) observed interference from the existence of PEAR in semantic categorization of PEER (though this was weaker than the interference from DEER on the categorization of DEAR). PEER will activate the orthographic representation of PEAR to some extent via sublexical O-P-O rebound (EE → /i:/ → EA). Similarly, Treiman et al. (1983) found a high error rate when judging the acceptability of sentences like MY FAVORITE FRUIT IS A PEER.

It should be noted that the error rate in the Treiman et al. study was higher when the competing word was regular than when it was irregular (e.g., A PERSON OF EQUAL RANK IS A PEAR, where the competing word, PEER, is regular) and this would be expected from O-P-O rebound because the competing word will be supported by sublexical phonology when it is regular (i.e., the /i:/ of PEER will be activated by the EA of PEAR), but not when it is irregular (i.e., the /ɛ/ of PEAR will not be activated by the EE of PEER). In fact, the non-homophonic items in the study of V. Coltheart et al. (e.g., PEER) contained a mixture of words with regular and irregular competitors and it is possible that an effect of similar size to that of the homophonic items (e.g., DEAR) would have been observed if only words with regular competitors were used (e.g., BEAR being mistaken for BEER rather than PEER being mistaken for PEAR).

The point about O-P-O rebound is that an

orthographic lexical unit is activated not only by activation passing up from sublexical orthographic units, but also from rebounding phonological activation. As a result, when LOOT is presented, activation of the phonological lexical unit for /lu:t/ will be quite rapid (as a result of the supportive activation coming up from the sublexical phonological units) and this, in turn, will rebound to activate the orthographic unit for LUTE (as well as LOOT) via both sublexical and lexical units.

Now, consider Fig. 2 without a link between the P component and the S component. Even though such a system lacks an O → P → S pathway, the meaning of the homophonic partner of a target word will nevertheless be activated. O-P-O rebound will activate the orthographic representation of homophones and it is this that can create false alarms in the semantic categorization task, delays in sentence acceptability judgements, priming of a semantically related word, and even variations in eye movements and fixation times. So all of the findings that use homophony as the manipulation of phonological involvement in semantic access could equally be explained in terms of an O-P-O → S pathway. In other words, while phonology might be automatically activated in silent reading, there is no definitive evidence of a pathway leading directly from phonology to meaning.

The obvious response to an argument like this is that language is first and foremost a phonological medium and, therefore, a link between phonology and semantics is an axiom of language representation (e.g., Frost, 1998). Spoken words are able to be understood, so there must be a link between phonology and semantics. Of course, this is true. But the link between phonology and semantics need not be found in the component that is directly linked to orthography. That is to say, the P component that has been discussed so far, does not need to provide the interface of the lexical processing system with the spoken signal nor is it a set of articulatory representations. Instead, it can be seen as an abstract phonological representation that provides a linkage between the surface phonetic representation and orthography (see Taft, 1984, and Taft & Hambly, 1985, for elaboration of this idea).

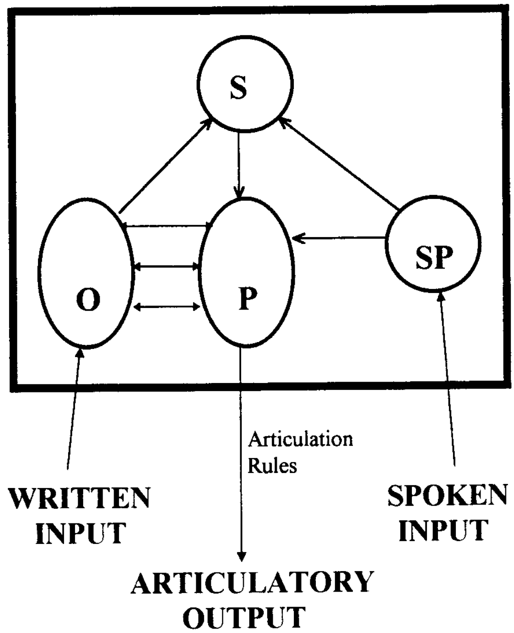

FIG. 3. Schematic representation of the lexical processing system with phonological information (P) acting as a way-station between surface phonetic form (SP) and orthographic information (O) and between semantic information (S) and articulatory output. The S component is only accessible via O and SP.

As an example, many dialects of English pronounce DEAR without a final /r/ (giving something like /di:∂/), but if the lexical P representation for DEAR were actually /di:∂/, it would not receive supportive activation from the lowest sublexical level where D → /d/, EA → /i:/, and most importantly, R → /r/. Therefore, it may be the case that the lexical P representation is /di:r/ even for those who do not pronounce it that way, and that the spoken output which replaces /r/ with /∂/ is generated from this by an articulation rule. When the spoken word [di:∂] is to be processed, the lexical processing system is entered through a surface phonetic representation (SP) which will then activate the appropriate P representation, though maybe only if the orthographic representation is required. Such a system is depicted in Fig. 3.

Within this framework, meaning is only ac-

cessible via the surface phonetic form when the input is spoken or via the orthographic form when the input is written. The abstract phonological representation is merely a way-station between orthography and articulatory output when reading, between semantics and articulatory output when producing speech, and between the surface phonetic representation and orthography when the latter is required in response to spoken input. This is the strongest possible version of this approach. That is, there is no direct link from phonology to meaning. Developmentally, the individual will initially learn a simple SP → S mapping in order to understand speech. Learning to read might at first involve the development of the O → P mapping so that the word can be overtly articulated and have its meaning accessed via the SP → S route. Only with increased proficiency does it become possible to go directly from orthography to meaning without overt articulation (i.e., via an O → S route).

It is still being proposed that the P component is automatically activated in silent reading, but not for the purposes of accessing meaning. The reason for its activation is purely to allow an articulatory output to be generated and this output may be required for the purposes of holding the word in working memory (e.g., Baddeley, Eldridge, & Lewis, 1981; Kleiman, 1975). It should be noted that the articulatory output can take the form of subvocalization, with overt pronunciation only required when reading (or speaking) aloud.

As mentioned earlier such a model is highly speculative, and it is certainly arguable that there should be a link between the P and S components within such a system, but it can be seen that such a link need not be an important one since the system can function perfectly well without it. Nor is it necessary to postulate such a link to account for effects of homophony, since these can alternatively be explained in terms of O-P-O rebound (or feedback phonology).

CONCLUSIONS

The experiments reported in this paper provide no evidence for O → P → S processing when regularity rather than homophony is used as the diagnostic for activation of the P component. While it is necessary to rely on a null effect to draw such a conclusion, this must be seen in the light of the fact that other effects are revealed when using the same task. One can conclude from this that there is both a phonologically mediated and a non-mediated route to meaning that act in parallel, albeit following different time courses. Alternatively, it is possible to make a case for the strongest position that the only route to semantics in silent reading is the non-mediated one, and this is quite the opposite view to most recent publications on the topic.

APPENDIX

The following are the regular and irregular words used in Experiments 1 and 2, as well as the high frequency words and given names that were used in Experiment 2.

Irregular	Regular	High frequency	Given names
WART	WIG	GOLD	LYN
BROOCH	BRINE	BOAT	JOEL
WAND	WHISK	FIELD	TRENT
SIEVE	SWIRL	SHIP	RUTH
MONK	MASH	BOX	WALT
SOOT	SLEET	HORSE	WAYNE
GIN	JEST	TOWN	GEORGE
STEAK	SCALP	FIRE	TIM
PEAR	POUCH	SPACE	JOHN
VASE	VINE	TREE	LUKE
PINT	PLANK	BLACK	LEE
GLOVE	GAP	FISH	LIZ
SEW	SAP	CAR	JANE
CROW	COIL	FOOD	KATE
BREAST	BRIDE	LAND	CARL
WORM	WAX		JAMES
STAFF	STEM		BEN
SOUP	SLAVE		STEVE
WOOL	WASTE		BRETT
THREAD	THROAT		MATT
			BETH
			ANNE
			ROY
			NEIL
			PHIL
			PAM
			CHRIS

The following are the test items used in Experiment 3.

Transposable letter (TL) words	Matched controls
COLT	CLAP
WRAP	WARN
GRAB	GOLF
SUNG	SLIP
BOLT	BAIT
SPLIT	SKIRT
COLD	CORN
SALT	SAND
FORTH	FRESH
CALM	CLUE
FITS	FOLD
BUGLE	BREED
BARN	BIRD
BURNT	BARGE
SLAVE	SLOPE
SWAN	SLOT
CARVE	CREST
TRAIL	TRAIN
BEATS	BURST
SANG	SAIL

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(Received March 12, 1997)
(Revision received September 9, 1997)