# Phonological recoding and lexical access in visual word recognition

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# Abstract

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The possibility that lexical access in fluent readers of English is phonologically mediated was examined using a modification of the semantic categorization paradigm employed by Van Orden (1987). It was predicted that if speech-based representations mediate lexical access, then more false positive category decisions should be made to phonologically ambiguous stimuli than to visual controls. For example, the homophone BEECH was expected to be treated as a member of a previously presented category - PART OF AN OCEAN SHORE - more often than its spelling control BENCH. It was further predicted that in the case of pseudowords, this effect would be restricted to stimuli whose orthographic structure conformed to rules of English spelling. These hypotheses were tested in three experiments. Homophone stimuli from Van Orden's study were used in a preliminary study, and a phonological effect was found. In a second experiment, masked pseudoword stimuli like BRANE were presented to subjects at threshold presentation rates. Despite the poor viewing conditions, the phonological effect found with homophone stimuli generalized to these new conditions suggesting that phonology was activated prior to and early enough to influence lexical access. In a

third experiment, however, it was found that the effect did not generalize to a set of pseudowords that consisted of strange letter sequences such as KWYTE. Together the present findings suggest that phonological codes may be activated pre-lexically, but experimental evidence of this phenomenon is restricted to studies employing stimuli that follow orthographic rules of the targeted language.

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The question addressed in this thesis concerns the role spoken language plays in accessing a word's lexical entry in skilled reading. More precisely, this thesis examined whether lexical access is achieved directly from the visual representations of words, or whether pre-lexical phonological activation is an inherent part of the word recognition process.

Some models of word recognition proposed that lexical access proceeds directly from print to meaning (Green & Shallice, 1976; Smith, 1971) without reference to phonology while others proposed an indirect route from print to sound to meaning (Gough & Cosky, 1977; Rubenstein, Lewis, & Rubenstein, 1971). Research over this question has yielded mixed results and gave rise to the development of dual access models which allow for the influence of both visual and phonological codes. For many of these models, however, the effect of phonology is either an epiphenomenon created by task demands (Coltheart, Davelaar, Jonasson, & Besner, 1977), the result of automatic activation that is most often too slow to affect the lexical identification process in normal reading (Dennis, & Newstead, 1981; Underwood & Bargh, 1982; Waters & Seidenberg, 1985), dependent on reading skill (Backman, Bruck, Hébert, & Seidenberg, 1984; Waters, Seidenberg, & Bruck, 1984), task specific (Waters & Seidenberg, 1985), or finally, the reflection of an optional strategy under controlled processing (Davelaar, Coltheart, Besner, & Jonasson, 1978; Hawkins, Reicher, Rogers, & Peterson, 1976; McQuade, 1981; ). Thus, although phonological effects have been observed under certain experimental contexts, two main issues remain to be resolved.

The first one concerns the issue of automaticity. Demonstrations that the activation of phonology may be suppressed when it is detrimental to task performance still provide no answer as to the automaticity of such activation. Paradigms which allow for the emergence of controlled processing may obscure effects due to automatic processing. To the extent that skilled reading involves phonology, it is important to investigate the possibility of automatic activation under specific experimental contexts which allow for the emergence of such effects.

A second issue relates to the locus of phonological activation. There is little controversy about the usefulness of phonological codes in working memory as referent codes (Perfetti, & McCutchen, 1982; Perfetti, 1985). The question is whether these are useful in accessing a word's lexical entry.

A survey of the literature shows the two issues to be inter-related. Thus, while evidence of automatic phonological activation has been found, (Dennis & Newstead, 1981; Humphreys, Evett, & Taylor, 1982; Lupker, 1982; McQuade, 1983; Perfetti, Bell, & Delaney, 1988; Tanenhaus, Flanigan, & Seidenberg, 1980; Underwood & Thwaites, 1982), there is little consensus as to the locus of such activation.

Some of the paradigms employed did not allow one to disambiguate pre- from post-lexical processes. For example, some studies used a modified version of the Stroop paradigm and showed that words that were phonologically related to the word referring to a picture or the color of a card created more interference to picture or color naming than visual controls (Dennis & Newstead, 1981; Lupker, 1982; Tanenhaus et al., 1980). The question as to the locus of such interference effects, however, remains open. More suitable paradigms have been used in other studies and results favor either the pre- or post-lexical hypothesis (see Perfetti et al., 1988 for pre-lexical evidence; and Humphreys et al., 1982; Underwood &

Thwaites, 1982 for post-lexical effects). There is also evidence to suggest that the type of phonological representation that is held in working memory may be different from that which serves lexical access (Besner & Davelaar, 1982).

The goal of this thesis therefore, was to address the question of phonological recoding by using a paradigm suitable to address both the issues of automaticity and locus of phonological effects.

The lack of consensus reported in the literature over the role of phonology in lexical access can in part be attributed to methodological considerations. Usually, a test of the phonological hypothesis involves manipulating the phonological characteristics of words presented and examining the impact this has on task performance. Such tasks may include lexical decision tasks, naming, tachistoscopic reports, visual search tasks, same-different judgements, semantic decision tasks, etc. The most widely used tasks, however, are the lexical decision task which requires subjects to decide whether a letter string presented is a word or not, and the naming task. Difficulties in interpreting results with regards to both the automaticity and locus of activation issues may arise from two sources: 1) problems regarding the manipulation of phonological characteristics of the target stimuli, or 2) problems related to the task chosen. These will be reviewed in turn.

Manipulations of phonological characteristics

Spelling-to-sound correspondences

Accessing the lexicon through phonological mediation requires that some kind of rule be applied to convert constituent parts of the visual code into a speech based representation. One possibility which has been extensively researched is that the letter string is analyzed into constituent graphemes (letter or letter clusters) and that the reader employs an internal system of rules to convert these into phonemes. Venezky (1970) described a system of grapheme-phoneme correspondence (GPC) rules that works for the majority of English words but fails to produce the right phonological code for a minority of words. In this respect, English has been described as a quasi-regular system (see Henderson, 1982 for discussion). Thus, some words are considered exceptions because GPC rules fail to produce the correct pronunciation (e.g. HAVE is the exception to GPC rules as applied to GAVE, RAVE, SAVE, CAVE, etc.) This characteristic has allowed researchers to test whether printed word identification involved phonological recoding by manipulating the degree of spelling-to-sound regularity of words presented in naming and lexical decision tasks. If in fact, the reader phonologically recodes visual representations of words, then exception words should take longer to name or identify than regular words because the conversion process would yield an incorrect phonological representation. If on the other hand, word recognition proceeds directly from abstract visual codes, no differences between each type of word should occur.

Evidence concerning regularity effects is mixed. It seems that regularity effects are more readily found in studies requiring overt pronunciations than silent reading. For example, while degree of spelling-to-sound regularity of words affected naming latencies (Baron & Strawson, 1976; Seidenberg, Waters, Barnes, & Tanenhaus, 1984, Stanovich & Bauer, 1978; Waters & Seidenberg, 1985; Underwood & Bargh, 1982), lexical decision times were unaffected by this factor (Andrews, 1982; Coltheart, Besner, Jonasson, & Davelaar, 1979; Seidenberg et al., 1984; Waters et al., 1984). Furthermore, variable effects of regularity have been reported according to the definition one applied to regularity (Parkin, 1982; 1984).

Others still have challenged the regularity effect on the basis that exception words are also strange from the viewpoint of orthography (Parkin, & Underwood, 1983; Seidenberg et al., 1984; Waters & Seidenberg, 1985). This possibly confounding variable might explain the longer decision latencies reported on exception words relative to regular ones. Seidenberg et al. (1984) tested this hypothesis in a study using both the naming and lexical decision tasks. They found effects of both irregular spelling and pronunciation on naming latencies while lexical decision latencies were only affected by irregular spelling. The effects, however, were restricted to low frequency words. This led them to conclude that while high frequency words are processed on a visual basis, the slower recognition process of low frequency words allows for phonological information to develop and influence lexical access. Task differences on regularity effects, they argued, are due to the time considerations involved in completing the tasks. While naming necessarily depends on the outcome of a phonological process, lexical decisions could sometimes be reached before this process was completed (see also Andrews, 1982).

The psychological validity of regular/exception classification of words has been challenged by Glushko (1979). The fact that readers possess knowledge of spelling-to-sound rules may not in itself be indicative that such knowledge is used in word recognition and pronunciation. He proposed instead an "activation-synthesis" model in which words are recognized and pronounced via an analogy process. Incoming words activate a cohort of neighbors with similar spelling patterns and associated phonological information. According to this model, exception words take longer to recognize because of the inconsistent pronunciations activated by words sharing similar spelling patterns with them. Similarity here is defined in terms of word endings or rhymes (the pattern HATE for example, activates words like DATE, LATE, and RATE, and the pattern CAVE activates words like GAVE, HAVE, RAVE, and SAVE). This model predicts that words with consistent neighborhoods will be recognized faster than words with inconsistent neighborhoods even though each may be regular in terms of their own individual spelling-to-sound correspondences. Glushko confirmed this hypothesis by showing that lexical decision latencies to regular words like HATE were faster than those to regular-inconsistent words like CAVE. Bauer & Stanovich (1980) replicated these results and argued that some studies may have failed to find regularity effects because the regularity variable was confounded with consistency.

Further investigations revealed that consistency effects may also be limited to lower frequency words (Andrews 1982; Seidenberg et al. 1984, Expt. 4) while others failed to find any consistency effect at all (Stanhope & Parkin, 1987, Expt 3; Seidenberg et al., 1984, Expt. 1). Moreover, Andrews (1982) found that both consistency and regularity variables affected naming latencies to low frequency words. Andrews interpreted these data in the context of both dual-access and analogy models. She proposed that spelling-to-sound correspondence rules govern the slower phonological route while the faster visual route is influenced by a word's lexical neighborhood.

The consistency and regularity distinctions were rejected by Brown (1987) who identified a factor overlooked in other studies, namely, the frequency with which a word body (as related to word ending or rhyme) is associated to a regular pronunciation. Seidenberg & McClelland (1989) argued that failure to equate stimuli on this factor may explain the failure to find consistency effects in some studies. That is, the influence of a single exception word on its regular inconsistent neighbor may be overshadowed if the regular pronunciation is associated to a large number of words.

The picture emerging from the studies reviewed so far indicates that more than one factor is implicated in the word recognition process. To be viable, theoretical distinctions of regularity must accommodate factors related to frequency of occurrence as well as consistency and size of a word's lexical neighborhood. As Seidenberg & McClelland (1989) argued, the orthography of a language encodes several types of information pertaining to overall frequency, word body frequency, orthographic redundancy, etc. "Knowledge of English orthography can be seen as an elaborate matrix of correlations among letter patterns, phonemes, syllables, and morphemes" (p.525). Failure to account for these confounding factors in regularity studies may explain the lack of consensus reached so far as to which route governs lexical access.

Furthermore, Treiman & Zukowsky (1988) emphasized the need to identify the kind of multi-letter units that readers use. This information is critical to both analogy and dual-route frameworks. Without this knowledge, they argued, the models could not be tested or compared. Manipulations of phonological characteristics of words as they relate to spelling-to-sound regularity, therefore, are difficult to defend without giving consideration to the study of critical letter constituents involved in reading.

Homophony

Another strategy used to test the phonological hypothesis is the investigation of homophone and pseudoword processing on reading performance. Homophones have two lexical entries sharing the same phonological code (e.g., BEECH and BEACH). On the other hand, pseudowords have no lexical entry in terms of their orthographic code but can be mapped onto a lexical entry by their phonological code (e.g, BOTE as related to the word BOAT; note that this term has also been referred to as "pseudohomophone" in the literature). A number of researchers therefore have taken advantage of this "homophony" property in studies involving lexical decision, naming, and priming tasks. The general rationale was that if a reader phonologically recodes words and/or pseudowords prior to lexical access, then an effect of homophony should be observed above and beyond that of visual similarity.

Rubenstein et al., (1971) were among the first to investigate the issue of phonology within an information processing framework. In a first experiment, they used the lexical decision task and presented subjects with letter strings that formed either a pseudoword such as BRANE or a nonword such as SLUC. Pseudowords took longer to reject than nonwords, an effect which could only occur by virtue of mediating phonological codes. Furthermore, they compared decision times to words that were either homophones (SAIL/SALE) or nonhomophones (LAMP), and found that low frequency homophones took longer to accept than nonhomophones. Had lexical access proceeded on a visual basis, a single entry would have been located within the lexicon and no latency difference between homophones and nonhomophones would have been observed. The fact that a homophony effect was observed again was taken as confirmation that lexical access was phonologically mediated.

Later attempts to replicate Rubenstein et al.'s findings either met with failure (Frederiksen & Kroll, 1976; Martin, 1982; Taft, 1982), partial confirmation (Coltheart et al., 1977; Davelaar et al., 1978) or were successful (Besner & Davelaar, 1983; McCann, Besner, & Davelaar, 1988). A critical factor in these studies was the degree to which they controlled for certain confounding variables. For example, Coltheart et al. (1977) criticized the Rubenstein study on the grounds that homophones and nonhomophones were not matched on frequency and number of letters, factors they argued which are known to affect lexical decision times. Furthermore, the pseudowords and nonwords were not equated for visual similarity to real words. Superior visual similarity of pseudowords to real words may have accounted for the phonological effect observed.

Coltheart et al. (1977, experiment 1) investigated this possibility. When adequate controls for frequency, string length, and visual similarity were provided, they found a pseudoword effect but no homophone effect. Because effects of homophony were restricted to negative responses (i.e., longer *no* decision latencies to pseudowords relative to visual controls), they concluded that the effect was either an epiphenomenon, evidence of slow acting phonological codes not normally involved in lexical access, or the reflection of an optional strategy. The last explanation was retained by Davelaar et al. (1978; see also McQuade, 1981) in an experiment where phonological effects were found only when favorable to task performance. That is, when the stimulus set included pronounceable nonwords such as SLINT, latencies to low frequency homophones were longer than those to nonhomophones. On the other hand, when the stimulus set included pseudowords like BRANE, they observed no effect of homophony. The critical difference lay in the discriminating quality of the nonword environment. The sound of nonwords such as SLINT allowed easy nonword discriminations, whereas the sound of pseudowords such as BRANE produced high error rates that could be avoided if word processing proceeded on a visual basis. It seems then that subjects were able to take advantage of this factor as reflected by their differential performance to the nonword environments.

The issue of visual similarity of nonwords to real words is at the root of many studies concerned with homophone or pseudoword effects. A direct investigation of this factor was conducted by Coltheart et al. (1977, experiment 2). Based on the rationale that visual similarity of nonwords to real words affects lexical decision performance, these authors manipulated the visual similarity factor by introducing the N variable. The N value of a nonword corresponds to the number of words that can be produced by successive replacements of each individual letter with another, preserving letter positions. For example, BRANE has an N value of 7 by virtue of its similarity to CRANE, BRACE, BRAKE, BRAVE, BRAZE, BRAND, and BRINE. Using this measure, Coltheart et al. divided groups of words and nonwords into high and low N groups. While there was no effect of N on decision latencies to words, high N nonwords took longer to reject than low N nonwords. They interpreted these results in terms of Morton's (1969) logogen model. High N nonwords excite a higher number of candidate words than low N nonwords, thus lengthening the time for a decision to be reached.

In light of these results, Martin (1982) questioned whether pseudoword effects previously reported might not in fact reflect a higher degree of visual similarity of pseudowords to words relative to nonword controls. Coltheart et al. (1977, experiment 1) had controlled for this factor by changing one letter in the pseudoword to another (e.g., NEEN was considered a visual control of MEEN). Martin argued that this procedure did not ensure that both were as visually similar to real words. When Martin used instead the N measure as a visual control procedure, she found no latency differences between pseudowords and their visual controls. She therefore concluded that the pseudoword effect previously reported was not phonological but based on visual similarity.

Similar concerns were raised by Taft (1982). The visual control procedure he used, however, was not based on the N measure. Instead, pseudowords and their visual controls were constructed such that each one was as similar to *a* real word as the other. For example, the pseudoword GHOAST bore the same visual similarity to GHOST as the visual nonword control FROAST did to FROST. A nonword counterpart, PLOAST, was also constructed such that it was neither phonologically or visually similar to a single real word. The author argued that if lexical decisions are phonologically based, then a latency difference should occur between GHOAST and FROAST. If, on the other hand, the pseudoword effect occurs because of what he termed grapheme-grapheme conversion rules (as opposed to grapheme-phoneme conversion rules), then latencies to GHOAST and FROAST should be equal, but both should be longer than those to PLOAST which bears no visual similarity to real words. Results confirmed the latter hypothesis and he thus concluded that lexical decisions are based on grapheme-grapheme conversion rules (see also Taft, 1984).

Other studies that investigated the pseudohomophone effect also employed alternative methods of controlling for visual similarity. For example, McCann & Besner (1987) used a procedure based on summed positional bigram frequency (this procedure is based on Mayzner & Tresselt, 1965 and, relates to the frequency with which each pair of adjacent letters occurs in three- to five-letter words in the English language taking position into consideration). Other studies have controlled for the visual factor by changing as many letters in the visual control as in the pseudoword (Humphreys et al., 1982; Perfetti et al., 1988). Thus, MIAL and MIRL, were both considered as visually similar to MILE because both shared the same number of letters with their base word (i.e., two in each case). Others still used a very sophisticated procedure where a measure of the target's graphic similarity to the root word is derived by using a formula which takes into account number of letters shared, number of adjacent letters shared, and whether initial letters and final letters are shared (Van Orden, 1987).

Evidence concerning neighborhood effects on lexical access however, raises questions about the appropriateness of these alternative procedures. In a carefully controlled study, Andrews (1989) investigated frequency and neighborhood size effects (as reflected by the N variable used by Coltheart et al., 1977) on lexical access. She found that neighborhood size inhibited decision latencies to nonwords while it facilitated those to low frequency words. These results were interpreted within an interactive activation model where "partially activated neighbors boost the activation of sub-lexical components of the target and consequently strengthen target activation" (p.611). This process therefore would facilitate lexical access of low frequency words and inhibit nonword decisions.

The implications of Andrews' results with regards to studies manipulating nonword homophony are far reaching. Success or failure at finding homophony effects may depend on the degree to which pseudowords and their visual controls were equated on neighborhood size, namely the size of the N variable. One aim of the present thesis was to address this question by manipulating the degree to which nonword letter string sets conform to rules of English orthography.

Task considerations

In addition to issues relevant to the manipulation of the phonological characteristics of stimuli, several questions have been raised regarding the appropriateness of the various paradigms used in the investigation of the lexical access code. These will be reviewed in turn.

Lexical involvement

The investigation of the phonological hypothesis requires that the paradigm used allows for the observation of processes involved in lexical access and minimizes the contribution of post-lexical processes. Davelaar et al. (1977) were among the first to address this issue:

> It is our view that a number of experimental tasks from which the supporting data have been drawn are not logically appropriate and therefore cannot necessarily address the question concerning the nature of the lexical access code. (p. 391)

More specifically, they were concerned with the fact that many of these tasks can be performed with nonword letter strings: same-different judgments of phonological characteristics of stimuli, visual search for letters, naming, etc. As such, they argued, lexical access is at best optional since these tasks can be carried out without the involvement of lexical processes.

One task, they argued, which is a good index of lexical access processes is the lexical decision task. It requires subjects to consult the lexicon in order to discriminate between word and nonword letter strings, and thus ensures the involvement of lexical pr ses. They did qualify this statement, however, by saying that when the nonword set includes unpronounceable letter strings like BHHRND, then the decisions can be made on orthographic legality alone. On the other hand, when wordlike or pronounceable nonword letter strings are used, subjects must consult the lexicon in order to accomplish the task of deciding whether a letter string is a word or not.

Identification processes

The most compelling evidence favoring the phonological recoding hypothesis in lexical decision task was observed on 'no' responses to pseudowords (Besner & Davelaar, 1983; Coltheart et al. 1977; Davelaar et al., 1978; McCann et al., 1988; Segalowitz & Hébert, 1990). That is, longer response latencies were observed on pseudoword trials relative to nonword control trials. This was not true of word trials comparing homophone and nonhomophone words. The problem with the nonword data is that the latencies related to these trials are generally longer than those obtained on 'yes' trials. This led Coltheart et al. (1977) to consider the pseudoword evidence as an epiphenomenon, reflecting processes not normally involved in word identification. In order to be ecologically valid, clear demonstrations of phonological recoding, they argued, must be obtained on 'yes' trials. Data on homophones, however, failed to show evidence of phonological recoding.

Post-lexical involvement

Even with these considerations in mind, other problems concerning lexical decision data have been raised. There is evidence that post-lexical processes may be involved in the decision stage (Andrews, 1989; Balota & Chumbley, 1984; Seidenberg, Waters, Sanders, & Langer, 1984; for discussion, see also Humphreys, Evett, & Quinlan, 1990; Waters & Seidenberg, 1985). This makes interpretation of the data more difficult, as the effects of some variables may be overshadowed or inflated by decision processes having little to do with lexical access.

The criticism concerning the involvement of post-lexical processes may be applied to many of the paradigms employed. For example, naming includes a production stage where a word's articulatory code is formed. It may be that regularity effects observed in naming studies reflect processes involved in the production stage. One strategy that has been used to eliminate this possibility is to compare naming latencies obtained in immediate versus delayed naming conditions (see Mason, 1978; Andrews, 1989). The rationale was that if the effects observed in the immediate naming condition take place in the articulatory stage then they would persist in the delayed condition where lexical access has already been achieved. The fact however, that subjects are aware of this delay may allow them to anticipate the target name (i.e., prepare the articulatory code) prior to the deadline, a strategy which would be counterproductive to the methodological objectives pursued.

Automaticity

Another important point is that by manipulating stimulus onset asynchrony

(SOA) between prime and target in a lexical decision task with semantic priming, denHeyer, Briand, & Dannenbring (1983; see also Favreau & Segalowitz, 1983; Neely, 1977) demonstrated that both automatic and attention driven processes can influence lexical decision performance. Evidence that strategic factors may play an integral part of the lexical decision performance calls into question the pertinence of using this task to investigate the nature of lexical access codes. As mentioned earlier, strategic factors related to phonological recoding do not answer the question of whether phonology is an inherent part of lexical access. The possibility of controlled processing means that subjects have flexibility over the decision criteria they set to perform the task. This led Seidenberg & McClelland (1989) to argue that lexical access may not be a pre-requisite to task performance. That is, information about the familiarity of the stimuli at one or more levels may be used to guide the lexical decisions. Thus, depending on the dimension on which the letter strings differ (orthographic, phonological, or semantic) lexical decisions may be based on orthographic, phonological, or semantic characteristics.

Masking, pre-lexical processing and automaticity

Because word recognition is rapid and efficient in skilled readers, it is difficult to isolate processes involved in the early stages of word recognition. In order to maximize the possibility of observing the effects of pre-lexical processes on reading performance (or alternatively, reduce the contribution of post-lexical processes on task performance), masking techniques have been used (Bias & McCusker, 1980; Humpreys et al., 1982; Humphreys et al., 1990; Perfetti et al., 1988). Humphreys et al. (1990) argued that "because masking places strict limits on the information that can be explicitly identified from a word,... we may learn something about early word processing independent of effects due to response selection" (p.518). Others (Bias & McCusker, 1980) have also argued that masking techniques may reproduce conditions more similar to the reading situation whereby subsequent fixations act as a sort of mask to the word previously read.

Using this technique in a target identification task, Perfetti et al. (1988) found evidence of pre-lexical phonological recoding. The mask that followed the target was either phonologically and visually similar to the target (HEAR-heer), visually similar (HEAR-heor), or different on both dimensions (HEAR-fode). Since masking effects are reduced in proportion with the visual similarity of the mask to the target, they reasoned that if phonological activation occurs pre-lexically, then they should observe additional masking reduction effects related to phonological similarity. They found masking reduction effects related to both visual and phonological similarity. Because the mask appeared before the identification process was completed, they concluded that the effect resulted from pre-lexical automatic phonological activation.

Many of the paradigms employed allow some flexibility over the mediating code used to access the lexicon (for review see McCusker, Hillinger & Bias, 1981). Subjects respond to task demands by exercising control over the type of lexical access representation that will maximize their performance. This factor alone must therefore be taken into consideration in the interpretation of lexical access studies. A masking procedure which precludes explicit use of word information may circumvent the problem by allowing the observation of automatic pre-lexical processes leading to word identification (for an alternative view, however, see McCusker, Gough, & Bias, 1981). Furthermore, in order to address Coltheart et al.'s (1977) criticism concerning the assurance that lexical access be achieved, the masking procedure must be used in conjunction with a task that requires processing at the semantic level.

Given the methodological considerations raised above, a second aim of this thesis was to investigate the phonological hypothesis using a paradigm that makes possible the observation of automatic pre-lexical processes leading to the semantic representations of words.

Purpose of the present study

To summarize, two important issues emerge from the literature reviewed so far. The first one concerns the type of manipulation of the phonological characteristics of the stimuli. The review shows that manipulations of spelling-to-sound regularity are complicated by assumptions concerning the type of rules and letter constituents used in converting the graphemic code to a phonological code. On the other hand, manipulations of the homophonic status of the stimuli do not require that assumptions be made over the operations involved in converting print to sound, and thus serve as a more direct test of the phonological hypothesis. One of the major criticisms directed at the use of pseudoword stimuli, however, pertains to the lack of control exercised over the visual similarity factor in many studies. That is, the degree to which pseudowords and nonwords controls are equated on their visual similarity to other words including the root word itself has not always been taken into account.

The other issue is related to the pertinence of paradigms used to investigate the nature of the lexical access code. It is methodologically preferable for the task chosen to meet the following requirements : 1) ensure that lexical access is achieved, 2) allow for the possibility of observing automatic processing if it exists, 3) look at evidence obtained on positive trials (e.g., *"yes"* lexical decisions) rather than negative trials (e.g., *"no"* lexical decisions), and 4) eliminate the contribution of post-lexical processes.

The considerations raised above are exemplified in three studies which served as the basis for developing the rationale of the experiments reported in this thesis. The results and procedure of each will be described in turn, after which a critical analysis of the methodologies employed will be provided.

Post-Lexical evidence

Evidence against pre-lexical activation of phonology was given by Humphreys et al. (1982). Using a primed word identification task with backward masking, the authors tested whether the identification of targets preceded by phonologically identical primes (e.g., MAID-made) would be facilitated relative to those preceded by yoked spelling controls (MAKE-made). Subjects were presented with a mask, a prime, a target, and another mask at presentation rates in the order of 30 ms. Subjects' task was to identify the target. The masking procedure was used to minimize prime identification such that priming effects (if any) would reflect automatic processing. They thus operationalized automaticity in terms of effects arising from primes that had not been explicitly identified. In this context, they argued, prime information could not be used intentionally to influence target processing. They found a phonological effect when targets were preceded by homophone primes (MAID-made) but not when they were preceded by pseudoword primes (MAYD-made). Because pseudowords (which can gain access to the lexicon only through phonological codes) failed to facilitate target identification, they concluded that the phonological effect obtained with homophone primes resulted from automatic post-lexical activation.

Pre-lexical evidence

On the other hand, Van Orden (1987; Van Orden, Johnston, & Hale, 1988) provided evidence of pre-lexical phonological activation in a series of experiments using a semantic categorization task. Subjects were shown category definitions and were asked to decide upon the category membership of the target words that followed. Van Orden (1987) hypothesized that if the sound of a printed word mediates lexical access, then subjects should misclassify (i.e., make false positive responses) targets that sound like real members (e.g., ROWS for the category FLOWER) more often than they do targets who only share visual similarity with real members (ROBS).

Results showed that subjects made more false positive responses to homophone foils than they did to yoked spelling controls, thus indicating that phonology influenced the semantic judgments. He also found, however, an effect of visual similarity in that subjects made more errors to homophone foils sharing a greater number of letters with real members ('meat-meet' share 3 same position letters while 'rose-rows' share 2 letters). For the similarly spelled homophone foils, the rate of false positives was 29% while for the less similarly spelled foils, the rate was 8% (base rate for spelling controls was in the order of 0% to 4%). Thus, he concluded that both the visual and phonological codes were involved in lexical access.

In a second experiment, he tested whether the effect of visual similarity would disappear if the target word was masked. He reasoned that by masking the target, lower level information (visual) would be erased while higher level information (possibly phonological) would be maintained. Using the method of descending limits, critical SOA between target words and pattern mask was individually determined during a pretesting phase where subjects had to classify a set of members and nonmembers of categories previously shown. Critical SOA was defined as the point at which subjects could no longer report targets that were not members of the target category (unprimed condition) while they could still identify most of the exemplars. Using this procedure, differences in false positive rates between similarly spelled and less similarly spelled homophones were no longer significant. Furthermore, the rate of false positives increased from 29% to 40% for the similarly spelled homophone foils and 8% to 46% for the less similarly spelled homophone foils. This general increase in the false positive rates was taken as an indication that due to the masking procedure, less information on the visual code was available, thereby hindering successful word identification on trials where homophones foils were presented.

Although the results of the two experiments described above indicate that phonological codes influenced semantic judgments, Van Orden examined the possibility that they may have reflected post-lexical processing. That is, a visual code may have accessed the correct lexical entry (ROWS), and this lexical representation may in turn have activated the homophone's lexical node (ROSE) through the activation of their common phonological representation (*/roz/*). Thus, as a result of the indirect activation of the exemplar's representation, homophone foils may have been mistakenly treated as exemplars on a number of trials. In order to clarify this issue, Van Orden et al. (1988) tested whether pseudoword foils would also cause subjects to make more false positive classifications. They reasoned that if subjects classify pseudowords as members more often than they do spelling controls, then the locus of the phonological activation must be pre-lexical since pseudowords cannot gain lexical access without phonological mediation. They found that relative to spelling controls, subjects made as many false positive errors to pseudowords as they did to homophone foils, and thus rejected the idea that the phonological effect found with homophone items occurred as a result of lexical access.

Methodological considerations

The contrasting results between Van Orden (1987; Van Orden et al., 1988) and Humphreys et al.'s studies can be explained on methodological grounds.

Humphreys et al. found that homophone primes facilitated target identification. This facilitation effect was not observed when pseudoword primes were employed. Because of this, they concluded that the locus of phonological activation must be post-lexical since pseudoword primes which hold no lexical status other than through their phonological codes failed to facilitate target identification. One can note, however, that the pseudowords they used were not equated on measures of visual similarity. The N value (as in Coltheart et al., 1977) sometimes varied dramatically within each pseudoword and spelling control pair. Furthermore, a high proportion (close to 25%) of the pseudoword strings consisted of illegal letter sequences. For example, they used pseudowords like KWYTE, KWENE, and FAYZE which all yield an N value of zero. As such, the process of recoding may have taken too long to exert any influence on lexical access. That is, the increase in processing time might have exceeded the time required for priming effects to influence target identification.

While Van Orden (1988) used a sophisticated measure of graphic similarity which controlled for the extent to which each pseudoword foil and its yoked spelling control resembled the orthographic structure of the root exemplar, they also failed to control for N. It remains possible then that the phonological effect obtained resulted from the greater visual similarity of the pseudowords to words in general. (This explanation, however, is unlikely because N is more critical to the lexical decision task than it is to semantic categorization tasks. That is, in the lexical decision task, the similarity of pseudowords to words in general is a critical factor in the word/nonword discrimination. On the other hand, the semantic categorization task requires subjects to decide upon the membership status of stimuli presented, not their lexical status. As such, the similarity of the pseudoword to the root exemplar is much more critical than the similarity of the pseudoword to words in general. For example, if a subject has to decide whether BRANE is a member of the category PART OF THE HUMAN BODY, the similarity of BRANE to BRAIN is much more important than the similarity of BRANE to other words that bear no relation to the category exemplar).

A more serious criticism concerns the fact that they did not include a masking procedure to test the pseudoword stimuli. The letter strings were not masked and remained on the screen until subjects responded. Although Van Orden's original reason for including this procedure in his 1987 study was to test whether effects of visual similarity found in Experiment 1 would disappear under a masking condition, the masking technique used in conjunction with nonword material also achieves a second goal: namely, to ascertain whether any effects resulting from the manipulation of the phonological variables on nonword stimuli are automatic and pre-lexical.

As described earlier, the masking procedure used by Van Orden et al. (1988) allowed subjects to identify a high percentage of words that were members of categories previously shown, while those that were not members could no longer be reported. Thus, the priming effects of the categories appear to have facilitated the classification of words which otherwise fell under identification threshold. It can be assumed then that because of the semantic activation generated by the prime, less input-information was needed from members than nonmembers for identification to occur. Under these conditions, a pseudoword effect can only be attributed to underlying phonological codes since visual information is no longer available to assist processing. That is, by the time masking interrupts visual processing, enough phonological information has been extracted for a match to occur between the pseudoword and the prime-activated lexical entry. It seems reasonable then to postulate that a pseudoword effect observed under these conditions would result from automatic pre-lexical activation.

The fact that Van Orden et al. (1988) did not use a masking procedure to test their nonword stimuli leaves the door open for a post-lexical interpretation of their results. That is, it is possible that the pseudoword effect arose as a consequence of lexical access in a manner similar to that described by Glushko (1979). According to this account, a target string activates a number of lexical entries on the basis of their visual similarity to it. These secondary activated entries give rise to phonological activation, thereby conferring an advantage to the pseudoword over the spelling control since the pseudoword shares more phonemic constituents with the root word. A masking procedure is useful to rule out this explanation since it prevents visual codes from assisting word recognition (or at least reduces the contribution of visual processing).

Recapitulation

To summarize, it seems that the lack of consensus between the two sets of studies reported above can be attributed to some of the methodological considerations that were raised. It is possible that Humphreys et al.'s (1982) failure to find evidence of pre-lexical phonological activation is due to the strange orthography of the pseudoword letter strings they employed. On the other hand, it is difficult to unambiguously interpret Van Orden et al.'s (1988) results because they failed to include a masking procedure with their nonword stimuli.

The experiments reported in this thesis were designed to address these methodological issues by using a semantic classification paradigm in conjunction with a masking procedure. The semantic categorization task was chosen for two reasons: first, the nature of the task requires processing at a semantic level thereby insuring that lexical access is achieved, and second, it allows one to observe identification processes involved on 'yes' trials (i.e., false positive responses).

A first goal was to test whether the pseudoword effect observed by Van Orden et al. (1988) would hold under threshold viewing conditions, more specifically where performance on member and nonmember trials would be respectively above and below threshold. It was predicted that if phonology is activated pre-lexically, then priming effects of category names should act on the activated phonological codes and raise pseudoword recognition above threshold, causing subjects to make more false positive categorizations on pseudowords than on spelling controls. Furthermore it was predicted that the phonological effect would be dependent on the legality of the pseudoword letter strings used. Thus, illegal letter strings such as those used by Humphreys et al.'s should not cause pseudoword false positive error rates to differ from that of their spelling control. These hypotheses were respectively tested in two experiments. The first used a set of legal pseudowords equated on the N variable while the second, a subset of the illegal letter strings employed by Humphreys et al. (1982).

Prior to testing these two hypotheses, a preliminary experiment was conducted to test whether the homophone effect obtained by Van Orden (1987, experiment 1) under a no masking condition could be replicated using a slightly modified procedure.

# PRELIMINARY STUDY

The experiment reported here is the last of a series of pilot studies conducted in an attempt to replicate the viewing conditions of Van Orden's masking experiment (1987) where most of the exemplars but few of the nonmembers were identified. The goal was to replicate those conditions to 1) test whether Van Orden's results obtained with words under masking conditions would generalize to pseudoword stimuli, and 2) further test the phonological hypothesis using Humphreys et al's pseudoword stimuli.

Due to equipment limitations, however, (the Apple video monitor paints one frame every 16.7 ms whereas the one used by Van Orden (1987) paints one frame every 10 ms) the original procedure had to be modified because it was very difficult to set an optimal presentation rate such that subjects would perform correctly on most members presented but on few of the nonmembers. That is, subjects were either accurate on both members and nonmembers, or failed to identify either. Eventually the simultaneous presentation of two letter strings instead of one in conjunction with a masking procedure was found to create a psychological impact on performance similar to that obtained with equipment permitting finer time frame gradations. Thus subjects were required to decide whether one of two letter strings was a member of a category previously presented.

In the course of developing the modified procedure for the masked semantic categorization task, an attempt was first made at replicating Van Orden's results (1987) with homophone stimuli. The same set of homophone stimuli used by Van Orden under a no masking condition was presented to subjects. This preliminary step was taken to test for the robustness of Van Orden's homophone effect, and ensure that the modification made to the original procedure did not significantly alter the nature of the task.

## Method

### Subjects

A total of 10 female and 7 male Concordia University students whose first language was English volunteered to participate in the study, and were paid five dollars. Data from 2 subjects were discarded because they performed too poorly on the member and nonmember experimental trials. That is, both had correct classification rates below 40% on these trials. Subjects were recruited from Psychology classes and various advertisements posted throughout campus. All had normal or corrected to normal vision.

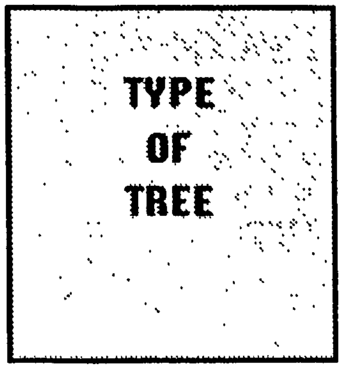
### Procedure

The session consisted of 204 trials of which 4 were practice. On each trial subjects were shown a category name followed by two target letter strings. For example, the category TYPE OF TREE might appear, followed by the target letter strings ELM and IJW. Subjects were told that one of these letter strings would *always* be a nonword. The other letter string could be one of the following: a member of the category previously shown (ELM), a nonmember (CAT), or another nonword (ZAT). They were instructed to decide whether one of the letter strings was a member or a nonmember of the category previously shown, and to indicate their response by pressing a "YES" or a "NO" key with their dominant hand. If they failed to identify any word at all (i.e., could not determine whether a word was included in the pair of letter strings that appeared on the screen), they were instructed to press a "?" key. They were also told to press the "?" key if they thought two nonwords appeared on the screen. The three keys were arranged in a triangular fashion on a panel placed in front of the subject. Speed and accuracy were stressed and no feedback information was provided.

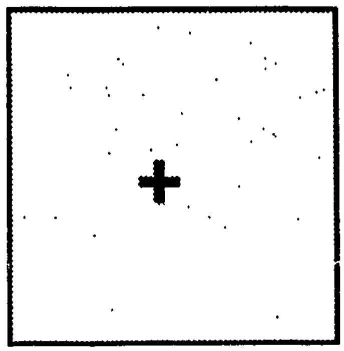
All stimuli were presented centrally on a video monitor controlled by an Apple IIe computer equipped with a software clock. Subjects were seated in a dimly lit quiet room approximately three feet from the monitor. The exact sequence of events within a trial was as follows: first, a fixation cross appeared on the screen for one second and was then followed by the category name which remained on the screen for two seconds. Then another fixation cross was presented for one second followed by the two target letter strings which appeared directly above and below the cross. An example of the type of trials presented is shown on Figure 1. (Note that the stimuli are not drawn to scale). The visual angle subtended by one target was approximately two degrees.

The order of trials was completely randomized for each subject and the experimental targets appeared equally often in the upper and lower positions. The background nonword appearing with the target was randomly selected from a pool of stimuli, the only requirement being that the background and target letter strings be of equal length. Latencies and type of responses were recorded by the computer. A typical session lasted approximately one hour.

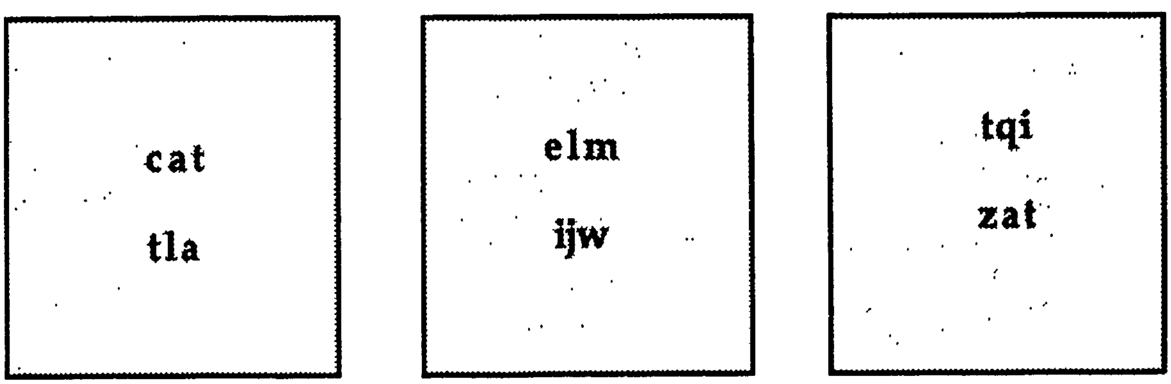
To ensure that false positive errors (if any) to homophone foils were not due to poor knowledge of the exemplar's correct spelling, a spelling test was given at the end of the session. (This procedure was implemented after the preliminary




1- A category name is first presented on the screen




2 - A fixation cross then appears on the screen




NO YES ?

3 - Finally one of three pairs of letter strings appear on the screen, and each pair is associated to a "No", "Yes", or "?" response.

**Figure 1. Example of the type of events forming a trial.**

study began so that only the last 10 subjects were tested on it.) Subjects were shown a list of the critical category definitions used in the experiment along with the pair of homophones (exemplar and foil) associated to each. For example, subjects would see the category name TYPE OF FOOD next to which the words MEET and MEAT were written. They were asked to circle the word whose spelling corresponded to that of the category exemplar.

Stimuli

A list of 200 experimental targets consisting of 20 homophones, 20 spelling controls, 40 category members, 40 category nonmembers, and 80 nonwords was constructed. The homophones and their yoked spelling controls were taken from Van Orden's study (1987) (see Appendix A). These stimuli were originally chosen such that the homophonic and control items were matched on a measure of graphic similarity to the root exemplar (see Van Orden, 1987 for details on the method used to derive graphic similarity measure), and on word length. Member and nonmember items were matched on frequency according to Kucera and Francis norms (mean frequency count of 73 (Se =12) and 81 (Se = 19) respectively, a non-significant difference by either raw or log frequency), on word length, and on number of syllables. For each pair of member and nonmember items, there were two yoked nonwords matched for length. The nonword items were all pronounceable nonwords. (See Appendix B for complete list of member, nonmember, and nonword items). Four words (2 members and 2 nonmembers) to be used as practice items were added to the list for a total of 204 target letter strings. Each target appeared only once.

A list of 204 non pronounceable nonwords to be used as background items was designed. The stimuli were constructed such that the proportion of letter strings of length 3, 4, 5, and 6 in the background set was the same as in the experimental set.

On the whole, the stimulus list was designed such that a "YES" response was required on 20% of experimental trials, whereas 40% required a "NO" response, and 40%, a "?" response. (Thus, there was a built-in bias towards negative responses (80% of trials) that worked against the phonological hypothesis which predicted positive responses on homophonic trials.)

Results

All the analyses were done using a within-subjects design. Responses above 2000 ms were not considered in the analyses Results are presented in Table 1. Reaction times to correct responses and percent correct responses between member and nonmember trials were compared using separate dependent t-tests. The mean percentage rate of correct classification of members and nonmembers was 78% and 65% respectively ($t$ (14) = 2.51 $p < .05$) demonstrating a statistically significant priming effect of category names on exemplars. There was also a significant priming effect on reaction times to correct classifications of members and nonmembers (921 ms and 1152 ms respectively, $t$ (14) = 5.60, $p < .001$).

A planned comparison between performance on trials involving homophones (MEET for the category TYPE OF FOOD) and those involving the yoked spelling controls (MELT) was carried out. Subjects made significantly more false positive errors to homophones (27.0%) than they did to spelling controls (9.3%) ($t$ (14) = 4.33, $p < .001$).

The mistakes subjects made in the spelling test were examined. Of the 10

Table 1.

Mean Correct Reaction Times and Percent Correct Responses on Member and Nonmember Trials, and Mean Percentage of False Positives on Homophone and Control Word Trials.

| | Mean | Se |
|---|---|---|
| | Percent Correct Response | |
| Members | 78 | 3.10 |
| Nonmembers | 65 | 5.65 |
| | Correct Reaction Times | |
| Members | 921 | 46 |
| Nonmembers | 1152 | 52 |
| | Percent False Positives | |
| Homophones | 27 | 2.96 |
| Controls | 9 | 3.83 |

participants subjected to this procedure, 4 made between 1 and 2 spelling mistakes. Two mistakes were made on the word NAVAL, and the rest were made on the words CREAK, MEET, and PEEK for a total of five mistakes. None of these spelling mistakes were associated with "YES" responses on the experimental trials concerned. Therefore, no further consideration was given to these findings.

## Discussion

The goal of the preliminary study was successfully attained in that results paralleling Van Orden's (1987, Experiment 1) were obtained using this modified procedure. The categorization of items was influenced by phonological factors causing homophone items to be classified as exemplars more often than control items. This effect occurred despite the fact that a negative response bias was built into the task due to the presence of a very high number of negative trials (80%).

Given this successful demonstration of Van Orden's main results, the phonological hypothesis was further tested using a masking procedure with pseudoword stimuli.

# EXPERIMENT 1

The purpose of this experiment was to examine whether the phonological effect found with homophones extends to pseudoword stimuli presented under a masking condition. Although Van Orden et al. (1988) did replicate the homophone effect with pseudowords, they did not include a masking procedure. This means that visual codes were fully available for analysis. It remains possible then that the exemplar's lexical node was accessed visually (in a manner following lexical analogy models), and that the phonological effect occurred post-lexically. In order to eliminate this possibility, a masking procedure was implemented in the present study. As in Van Orden (1987, Experiment 2), the purpose of the mask was to decrease the quality of the visual information such that stimuli which did not belong to a previously presented category (i.e., nonmembers) would fall under identification threshold. Relative to this baseline, category exemplars were expected to be identified significantly more often because of priming effects. Given the low level of visual information available for processing both pseudoword and control nonword targets, a phonological effect was expected only if phonological codes were generated pre-lexically to assist lexical access. In this way, the phonological information was expected to interact with the priming effects of category names, causing pseudowords to be classified as members more often than nonword controls.

The general procedure was identical to the one developed in the preliminary study. Subjects' task again was to decide whether one of two letter strings was a member of a previously presented category. In addition, however, a pattern mask immediately followed each pair of target letter strings, and presentation rates were individually assessed prior to the experimental task.

## Method

### Procedure and Stimuli

The basic procedure used in this experiment was essentially the same as that used in the preliminary study. Thus, a category name appeared on the screen followed by a pair of target letter strings. In addition, however, a pattern mask was presented immediately after the targets, and remained on the screen for 16.6 ms. Presentation rates were also individually assessed to ensure that viewing conditions caused subjects to perform at chance levels on nonmember trials. The session was thus divided into a calibration and an experimental phase.

#### Calibration stimuli

Two lists of stimuli were constructed Parts 1 and 2 of the calibration phase. The first list consisted of 4 groups of 20 target letter strings equally divided into nonmembers and nonwords (see Appendix C). The second list, to be used in the latter part of the calibration phase, consisted of 20 members, 20 nonmembers, and 20 nonwords (see Appendix D).

#### Calibration procedure.

Part I. The objective pursued in this phase was to establish a target presentation rate such that no more than 40% of the nonmembers would be correctly categorized. The 40% criterion was chosen to ensure that subjects performed below identification threshold on nonmember trials. To accomplish this, target letter strings consisting of nonmembers and nonwords (to a maximum of 40 nonmember and 40 nonword trials) were presented in a fixed order at very fast presentation rates (below identification threshold). The presentation rate was increased by one screen cycle (16.6 ms) every twenty trials until subjects successfully classified 40% of the nonmembers. In order to ensure that "NO" responses reflected a close approximation of the true negative rate, performance on nonword trials was also assessed. If "NO" responses were made more than three times on successive nonword trials, the session was interrupted and subjects were reminded to press the "YES" or "NO" keys only upon identifying a real word on the screen.

Part II. Once the criterion was reached, an additional set of 60 trials consisting of 20 members, 20 nonmembers and 20 nonwords randomly ordered was presented. Performance on nonmembers was also calibrated during this latter part as it sometimes departed from the criterion level reached in the first part. Thus, after each presentation of ten nonmember trials, the presentation rate was increased or decreased by one screen cycle if performance departed from the 40% criterion level. Once the 60 trials were completed, participants were told to take a few minutes to rest while the experimenter analyzed the data collected in this second part of the calibration phase. The presentation rate used for the last 20 calibration trials was identified and retained for the experimental phase. No feedback information was provided.

Although this procedure seemed to fulfil its purpose for most of the subjects tested, it sometimes happened that performance on nonmember trials was far above or below the 40% level by the end of the calibration phase. This seemed to occur because performance on the last 60 trials changed significantly faster than the calibration procedure allowed for. That is, since the presentation rate was adjusted by an increase or decrease of one cycle for every block of 10 nonmember trials, any drastic change in performance between blocks could not be caught up with. As a result, the experimenter determined a presentation rate for the experimental phase by adding or subtracting one cycle for every ten percentage points that departed from the 40% criterion level.

Experimental Stimuli

Other than a change in critical target items (the homophonic items and their spelling controls), the list of secondary targets (the exemplars, the nonmembers and the nonwords) was essentially the same as that used in the preliminary study. (A minor change on the member set had to be made because four of the pseudowords used as critical items were homophonic with four exemplars of the original list. The words DEEP, GREEN, SOAP, and TRAIN were thus replaced by the words CLAIM, SCREW, MEAN, AND CLEAR. These modifications, however, did not produce any significant change in the mean frequency of the exemplar list.)

Critical items now consisted of 20 pseudowords (e.g., TRANE for the category TYPE OF TRANSPORTATION) and 20 yoked spelling controls (e.g., TRAPE). Each pseudoword and its yoked spelling control were matched on number of letters (ranging from 3 to 5), CVC structure, on number of letters shared with the root exemplar, and on the letter strings' orthographic legality using Coltheart's N variable (1977). This variable as explained previously is a measure of the extent to which the spelling of a letter string resembles that of English words. It can be derived by counting the number of words that result from individually replacing each letter with another, preserving letter position. The resulting mean N value was 8.3 for both pseudowords and their spelling controls, and none had N values lower than 3 (a dependent t-test comparison of the N value of the two groups revealed no significant difference). A list of the pseudoword set and associated N values is presented in Appendix E.

Experimental Procedure

Except for the different viewing conditions, the procedure was exactly the same as that used in the preliminary study: subjects were tested on 204 trials of which four were practice. Although performance on nonmember trials was more stable during this phase, it was still necessary to adjust presentation rates following the criterion established for nonmember trials in the calibration phase.[1] In general, however, the change in presentation rates rarely exceeded two cycles above or below the one previously established. Mean presentation rate was 217 ms, with a range of 133 ms to 317 ms. A typical session lasted about one hour and ten minutes.

Subjects

A total of 28 volunteer students (15 females, 13 males) whose first language was English participated in the study. Data from fifteen participants was retained for analysis following the selection criteria described below. Participants were paid five dollars and were recruited from Psychology classes and advertisements posted throughout Concordia University. All had normal or corrected to normal vision.

Data selection criteria. It was critical to this study that viewing conditions cause subjects to perform around chance levels on nonmember trials and that the

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[1] This problem was also encountered by Van Orden (1987) who continued to adjust SOA between target and mask during the experimental procedure.

priming effects of category names succeed in significantly elevating member performance above that of nonmembers. Given this to be the case, the data regarding homophonic trials could then be correctly interpreted. Therefore, to ensure that viewing conditions met the criterion described above, it was necessary to consider data only from subjects who demonstrated priming effects under conditions where performance on nonmember trials fell below identification threshold.

Defining chance performance, however, was difficult to accomplish because it was impossible to determine chance levels for each of the three types of responses available to the subject, namely the "YES", "NO", and "?" responses. That is, because the experimental procedure as outlined below encouraged subjects to use a very conservative strategy (i.e., participants were instructed *not* to press the "YES" and "NO" keys *unless* they had identified a word), chance levels were not equally distributed across the responses. Consequently, a Chi Square analysis which would have been the best statistical technique to use on this type of data could not be applied in this situation.

With these considerations in mind, the problem was approached in the following way. Recall that the key element to this paradigm was the presence of priming effects under otherwise very poor viewing conditions. The problem then was to find a way of assessing actual identification rates on member and nonmember trials so that only data from subjects who 1) performed poorly on nonmember trials, and 2) showed a higher rate of identification on member trials would be included in the analyses. An indirect way to determine actual identification rates was to observe performance on nonword trials. The logic was that if subjects reliably refrained from pressing the "YES" or "NO" keys on nonword trials (i.e., refrained from making member "YES" or nonmember "NO" category decisions to nonwords) then proportion of word trials on which they did make the "YES" or "NO" response must reflect actual identification rates.

Consequently, a first criterion for retaining a subject's data was that the rate of 'YES' and 'NO' responses to nonword targets be very low, specifically not more than 15% of the nonword trials. A second criterion was that successful performance on nonmember trials fall below 60% to ensure that poor viewing conditions had been achieved. Finally, that performance on member trials be at least 10 percentage points higher than whatever rate was reached on nonmember trials to ensure priming had occurred.

Fifteen subjects met these performance criteria. Two planned comparisons (dependent t-tests) were carried out on their reaction time and percent correct responses to member and nonmember trials. Results are presented on Table 2. The mean percentage of correct classification of member trials (61%) was significantly greater than that of nonmember trials (41%) ($t$ (14) = 9.84, $p < .001$). These results of course were expected given that one of the criteria required that a 10% difference exist between these two types [illegible]ls. Reaction time data, however, corroborate this priming effect. That is, subjects were significantly faster on member trials (875 ms) than on nonmember trials (1045 ms), ($t$ (14) = 4.29, $p < .001$).

Together these results show that under very poor viewing conditions, category names significantly improved successful processing of exemplar targets.

Table 2.

Mean Correct Reaction Times and Percent Correct Responses on Member and Nonmember Trials.

| | Mean | Se |
|---|---|---|
| | Percent Correct Response | |
| Members | 61 | 2.05 |
| Nonmembers | 41 | 2.83 |
| | Correct Reaction Times | |
| Members | 875 | 63 |
| Nonmembers | 1045 | 70 |

Results

A diagram of the type of trials and responses involved in the experiment is presented on Figure 2. Cells included in each of the critical comparisons described below are highlighted. Cells that were involved in the priming effect analysis previously reported (i.e., comparison of correct responses on member and nonmember trials) are also highlighted on the Figure. All the analyses were performed according to a within-subjects design. Responses above 2000 ms were not entered in the analyses.

A first comparison involves the pseudoword and control nonword trials. Mean percentages of false positive errors to pseudowords that sounded like category exemplars (BRANE) were compared to those of the nonword spelling controls (BRAPE). Results are presented on Table 3. According to the phonological mediation hypothesis, letter strings which sounded like category exemplars were expected to cause more false positive errors than those sharing only visual similarity with category exemplars even though neither formed real words. A planned comparison between mean percentage error rate to pseudowords (18%) and the error rate to spelling controls (4%) confirmed the hypothesis ($t$ (14) = 3.66, $p$ < .005).

Another comparison involved "?" responses to presentation of the five different types of trials, namely the pseudoword, control, member, nonmember, and nonword trials. On word trials, the "?" response was expected to be used by subjects whenever information about the target was insufficient or unavailable for a semantic judgment to be made. Given the poor viewing conditions, it was predicted that "?" responses to word trials and nonword trials

Table 3.

Mean Percentage of False Positive Responses to Pseudowords and Nonword Control Trials.

| | Pseudoword | Control |
|---|---|---|
| M | 18.00 | 4.00 |
| Se | 3.58 | 1.11 |

would reflect the fact that subjects were unable to decide whether words or nonwords had been presented. In order to verify that "?" responses reflected a process by which word and nonword responses were undistinguishable (i.e., that on word trials, no lexical information was in fact available), reaction times to press the "?" key to the presentation of trials involving the 5 types of stimuli were analyzed. Given the above, it was predicted that no effect of stimulus type should be found on latency to respond. Table 4 presents mean reaction times associated with the "?" response as a function of stimulus type. A within group ANOVA on reaction times to press the "?" showed no effect of stimulus type on latency to respond. Thus, there is no evidence to indicate that this response reflected a process that was sensitive to the type of stimulus presented (see general discussion for more detailed description of the implications of these results). A table presenting the mean percentage response rate for each of the cells can be found in Appendix F.

Finally, "YES" and "NO" responses to nonword trials was examined. The difference between percent "YES" and "NO" responses to the presentation of nonword stimuli was analyzed in order to test for the presence of a negative response bias. Subjects made significantly more "NO" responses to nonword trials (4%) than they did "YES" responses (1%), ($t$ (14) = 2.32, $p$ <.05).

Results from the spelling test show that five of the participants made one spelling mistake each. Two of those mistakes were made on the word REAP, two on the word KEEN, and one on TEEN. When subjects' individual data were examined, however, none of these words were found to have been treated as members. Therefore, no further consideration was given to these findings.

Table 4.

Mean Reaction Times to '?' Responses on Pseudoword (P), Control (C), Member (M), Nonmember (N), and Nonword (X) Trials.

| | P | C | M | N | X |
|---|---|---|---|---|---|
| Mean | 907 | 850 | 831 | 871 | 844 |
| *Se* | 60 | 63 | 67 | 75 | 68 |

## Discussion

Results show that the pseudoword effect obtained by Van Orden (1988) holds under conditions where pre-lexical processing is interrupted by masking. The effect of semantic priming was to raise performance on members significantly above that of nonmembers as well as to decrease response time to members relative to nonmembers. The fact that more false positive errors were made on pseudowords relative to nonword controls under those conditions strengthens the argument that phonological codes assisted word recognition.

The finding that subjects selected the "NO" response more often than the "YES" response is not very surprising in light of the high proportion of trials requiring a "NO" response. It also suggests that the "NO" response rate to nonmembers might have been slightly inflated, which means that the actual difference between correct responses to member and nonmember trials might have been underestimated. It follows then that the estimate of the priming effect was, if anything, conservative.

Another implication follows from this result. The purpose for keeping the proportion of positive trials low was to discourage subjects from using the "YES" response. This way the false positive data could be interpreted with relatively more certainty than if subjects had been used to pressing that "YES" key more freely.

In sum, the results of the present experiment support the notion that phonological codes of pseudowords presented under poor viewing conditions were used to assist word recognition. The pseudowords and spelling controls were equated on a number of visual measures thus reducing the possibility that the effect was contaminated by factors related to lexicality. That is, the probability of making a false positive response on the basis of visual similarity to other words or to the root word was the same for the pseudoword and its visual control.

The pseudoword effect obtained in this experiment is not consistent with Humphreys et al.'s contention that phonological codes become available only after the lexicon is accessed. The possibility that their results might be due to the strange letter sequence forming their nonword stimuli was investigated next.

## EXPERIMENT 2

The goal of this experiment was to test whether the phonological effect obtained in Experiment 1 was contingent upon the type of stimulus used. Specifically, the concern was to replicate the testing conditions of Experiment 1 with a new set of pseudoword stimuli, namely a subset of those used in Humphreys et al.'s study (1982). The letter strings involved contained spelling patterns that violated rules of English orthography. It was predicted that this factor would prevent phonological codes from developing early enough to influence semantic decisions so that no differences in false positives would occur between pseudowords and their spelling controls.

### Method

#### Procedure

The procedure was identical to the one followed in Experiment 1. Individual presentation rates were first assessed during a calibration phase with the use of the same list of calibration words prepared for Experiment 1. Subjects were then tested on 204 experimental trials including the 4 practice trials. A spelling test on the set of homophonic letter strings used in the present experiment was also given to subjects (due to time considerations, one of the subjects could not complete this test). Mean presentation rate was 250 ms with a range of 150 ms to 333 ms.

#### Stimuli

Other than using a new set of pseudowords and their spelling controls to replace those used in Experiment 1, the list of experimental targets remained exactly the same. The 20 pseudowords and 20 spelling controls were selected from a set of stimuli used in Humphreys et al's second experiment (1982). As mentioned previously, a close examination of the pseudowords used in their study revealed that rules of English orthography (allowable letter sequences) were not followed in the construction of the letter strings. As a result, close to 25% of the letter strings in their study had N values between zero and two. For purposes of the present experiment, the pseudowords with the lowest N values were chosen (see Appendix G). The spelling controls originally paired with the pseudowords in Humphreys' experiment were then selected.

Subjects

A total of 27 students (23 females, 4 males) recruited from Psychology classes and various advertisements posted throughout Concordia University volunteered to participate. They were paid five dollars, and all had normal or corrected to normal vision. Data from 12 subjects were retained for analysis according to the selection criteria described below.

Data selection. The primary goal of this experiment was to examine the effects of "strange" nonword stimuli under the same viewing conditions as those of Experiment 1. Thus, an attempt was made to apply the same data selection criteria as those used in Experiment 1. It soon became evident, however, that in order to obtain the desired number of subjects satisfying these criteria, many more subjects than had been used in Experiment 1 would have to be tested (almost 66% more). The reasons for that are unclear. It seemed much more difficult to obtain subjects who would demonstrate a priming effect, that is, better classification rates on member than nonmember trials. Consequently, a sample size of 12 was chosen for this experiment (instead of the 15 chosen for the Preliminary study and Experiment 1).

Furthermore, differences of 8% rather than 10% between correct classifications of category exemplars and nonmembers were accepted (2 subjects out of 12 showed this difference: both had "YES" scores of 63% for member trials and "NO" scores of 55% for nonmember trials). Maximum performance on correct nonmember categorizations was raised from 60% to 65% (only 1 subject out of 12, however, demonstrated a percentage rate higher than 60% on nonmembers: this subject correctly classified 65% of the nonmembers relative to 75% of the category members). The criterion concerning performance on nonwords remained the same: "?" responses had to be made on less than 15% of the word trials.

Mean percentage of correct classifications for members was 77%, and for nonmembers, 57% ($\underline{t}\,(11) = 10.39$, $p < .001$.). Again this result was to be expected given the selection criteria. Reaction time data, however, support this finding. Results are presented on Table 5. Subjects were significantly faster in classifying members (648 ms) than they were in classifying nonmembers (800 ms), ($\underline{t}\,(11) = 5.74$, $p < .001$).

## Results

Again all analyses followed a within-subjects design, and responses above 2000 ms were not entered into the analyses. The mean percentages of false positives on pseudoword trials and spelling control trials were equal (mean of

Table 5.

Mean Correct Reaction Times and Percent Correct Responses on Member and Nonmember Trials.

| | Mean | Se |
|---|---|---|
| | Percent Correct Response | |
| Members | 77 | 2.16 |
| Nonmembers | 56 | 1.59 |
| | Correct Reaction Times | |
| Members | 648 | 57 |
| Nonmembers | 800 | 72 |

0.41%). This is due to one subject who showed a false positive rate of 5% on pseudoword trials and 5% on spelling control trials. None of the other subjects made false positive errors on either pseudoword or control trials.

Again, mean reaction times to press the "?" key as a function of type of stimuli presented (homophonic, control, member, nonmember, and nonword items) were subjected to a one factor ANOVA with repeated measures and no main effect of stimulus type on reaction time was found (see Table 6). A table presenting the mean percentage rate for each trial as a function of response is shown in Appendix H.

Subjects again made significantly more "NO" responses to nonword trials (7.5%) than they did "YES" responses (1%), ($\underline{t}$ (11) = 6.90, p < .001). None of the subjects made mistakes on the spelling test.

Discussion

In contrast to results found in Experiment 1, no pseudoword effect was obtained. This null finding was predicted on the basis of the strange or 'illegal' letter sequences forming the pseudowords.

The only factor that distinguished conditions in Experiment 1 and 2 was the set of experimental stimuli used. Thus, other than the new set of pseudowords and yoked spelling controls, the experimental context of Experiment 1 was replicated. A significant priming effect on correct responses and reaction times to members and nonmembers was obtained, and no differences emerged in reaction time to press the "?" key as a function of stimulus type. A negative response bias was also found such that subjects pressed the "NO" key more often than the "YES" key when presented with nonword stimuli.

Table 6.

Mean Reaction Times to '?' Responses on Pseudoword (P), Control (C), Member (M), Nonmember (N), and Nonword (X) Trials.

| | P | C | M | N | X |
|---|---|---|---|---|---|
| Mean | 708 | 710 | 766 | 733 | 736 |
| *Se* | 98 | 85 | 107 | 96 | 89 |

Clearly then, the cause underlying the contrasting results obtained in the present experiment (i.e., no pseudoword effect) must be attributed to a property of the pseudoword stimulus set. This property is assumed to be related to the strange letter sequences forming the pseudowords. Under poor viewing conditions, the masking of an already weak visual code (in terms of spelling familiarity) may have completely eliminated the possibility of deriving a phonological code so that priming could not affect pseudoword processing.

Within the context of the primed word identification paradigm used by Humphreys et al. (1982), this factor may have influenced the direction of results by affecting the processing time needed for the pseudoword to prime the target. That is, the unusual spelling patterns might have caused an increase in the processing time required to convert the stimulus into a phonological code. This in turn would explain why pseudowords failed to facilitate word identification. That is, a phonological code might not have developed fast enough to prime subsequent word recognition.

# GENERAL DISCUSSION

The purpose of this thesis was to examine whether phonological codes assisted printed word identification. To this end, an attempt was made to find out whether semantic decisions were mediated by the phonological properties of pseudoword foils presented under masking conditions. Thus, it was predicted that the stimuli's phonological code would mediate a lexical match between the target foil (BEAF) and the correct lexical entry (BEEF), above and beyond that caused by a visual match (BEEL).

In Experiment 1, results showed that subjects made more false positive errors to pseudoword foils than to spelling controls, thus confirming the hypothesis that phonological codes mediated semantic responses. A visual similarity interpretation was ruled out because both types of letter strings (pseudowords and control nonwords) were equated on the extent to which their spelling pattern resembled that of other English words (as measured by the N value), and were also equated on their respective similarity to the root exemplar. (Only shared letters in the same position are considered here since evidence from Perfetti et al. (1988) and Humphreys et al., (1990) have shown that shared letters out of position do not contribute either to orthographic priming effects or to reduced prime masking effects on target identification. It was therefore not considered to be a confounding factor in the results.)

It was further hypothesized that the phonological effect would be dependent on the orthographic legality of the letter strings used. Thus, given the same experimental context, the phonological effect was not obtained with letter strings whose spelling pattern did not conform to rules of English orthography, as reflected by results from Experiment 2.

Together, these results show that when 'legal' pseudoword foils are used, phonological properties of the stimuli influence semantic decisions, causing subjects to misclassify pseudoword foils as exemplars of target categories more often than spelling control nonwords. These results are consistent with those of Van Orden (1987; Van Orden et al., 1988) who found phonological effects with both words and pseudowords presented under normal (no masking) conditions.

These results also suggest that Humphreys et al.'s (1982) failure to find priming effects with pseudowords may be attributed to the strange spelling patterns of the letter strings they used. Given that Humphreys et al.'s position on the locus of phonological effects (i.e., post-lexical) was based on the lack of a pseudoword facilitation on target identification, the conclusions they reached are on less firm ground. Had they used 'legal' sets of letter strings, it is possible that a facilitation effect arising from pseudoword primes would have been obtained. [2]

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[2] In a priming study examining the processes involved in the construction of lexical access codes, Humphreys et al. (1990) have since revised their position on that aspect. Indeed, they have admitted to the possibility that their stimuli might not have been adequate in disambiguating phonological from orthographic priming effects. Their interpretation, however, is different from the one presented above. They base their argument on the view that the construction of a phonological code may involve a consonant base frame (McCann & Besner, 1987). This view holds that because spelling-to-sound correspondences for consonants (but not for vowels) in English are fairly regular, these may serve as a fairly secure phonological frame against which different vowel sound candidates are generated. Humphreys et al.'s (1982) pseudoword primes and target words often shared the same consonant frame with substitutions occurring at the vowel level (DROO/drew). They argue that "if consonant based phonology is important for priming, few differences may emerge between these two conditions" (p.555). In the 1990 study, Humphreys et al. present evidence or orthographic priming effects on target identification, with an emphasis for

Given these null effects, no further mention will be given to Experiment 2's results. Rather, the discussion will now proceed to the implications of the pseudoword effect obtained in Experiment 1.

Experimental context

The experimental context within which the results occurred was critical to the interpretation of the data. It was argued before that in order to unambiguously determine that the effects reflected automatic pre-lexical processing, a masking procedure which interrupted early word processing was necessary. The masking procedure as used in these experiments was intended to prevent identification of targets which were not members of previously presented category. The goal was to examine performance within the context of threshold viewing conditions where target identification was significantly enhanced by priming effects of category names on exemplars. Consequently, only those data from subjects whose correct performance on member trials was at least 10 percentage points higher than on nonmember trials were examined. Results from reaction time data to correct classifications are consistent with the priming assumption in that subjects were not only better but they were faster at classifying members than nonmembers. Correct classifications for members and nonmembers in Experiment 1 was 61% and 40% respectively. Although the difference between correct classification of members and nonmembers is smaller than that found in Van Orden's (1987) study, the priming effect is still significant. This means that under very poor viewing conditions, category names contributed to significantly

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letters in beginning and end positions which usually represent consonants in English four-letter words. They suggest that the orthographic effects thus observed may be based on abstract phonological units.

elevate member identification rates over that of nonmembers. The implications about the contrasting results between this study and Van Orden's, however, merit consideration, and will be addressed later in the discussion.

Because these results were critical to the design of the experiment, it was necessary to ensure that these responses were reliable, that is, that they reflected actual identification rates. Three types of trials were presented, the member, nonmember, and nonword trials for which three responses could be made, namely the "YES", "NO", and "?" respectively. This means that on a number of trials, subjects may have made incorrect "YES" and "NO" responses to nonword stimuli, thus making the "YES" and "NO" data less reliable.

In order to eliminate this possibility, only data from subjects who made no more than 15% "YES" and "NO" responses to nonword stimuli were included in the analysis. This ensured that subjects did not indiscriminantly use the "YES" and "NO" keys to select their responses to word stimuli.

Finally, an analysis on reaction time data to select "?" responses as a function of stimulus type (homophonic, control, member, nonmember, and nonword) was performed to further ensure that the "?" response was used to indicate that no word had in fact been identified. Subjects' instructions were to press the "?" key, either when two nonword letter strings appeared on the screen, or when they were unable to identify the letter strings. It was hypothesized that if subjects had processed lexical information about the word stimuli relative to the nonword stimuli even when they responded not having identified a word on a particular trial, then there should be an effect of stimulus type on reaction times to press the "?" key. That is, "?" responses to word trials were expected to be longer than nonword responses only if subjects had processed lexical information about the word stimuli. The analyses show that no significant differences emerged. It seems reasonable then to assume that this response reflected a unitary process by which nonword responses and failure to identify word stimuli were undistinguishable. Had there been differences in reaction times to word trials relative to nonword trials in selecting the "?" key, then one would have had to question whether "?" responses to word stimuli truly reflected non identification, and indirectly, whether the "YES" and "NO" response rates were reliable.

To summarize, the evidence indirectly supports the argument that "YES" and "NO" responses reflect identification rates. Under threshold viewing conditions, subjects were significantly better and faster at identifying category members. The fact that a phonological effect was obtained under these conditions suggests that phonological codes were generated early enough to assist word recognition.

According to Van Orden's results (1987, Experiment 2), masking eliminated the contribution of visual codes in lexical access, making the rate of false positives to the more visually similar homophone group equal to that of the less similar visually homophone group (e.g., BEECH/beach versus ROWS/rose). Although the stimulus list of Experiment 1 of the present thesis had not been constructed along this dimension, that is along a high versus low similarity dimension, a decision was made to examine responses made to stimuli bearing greater visual similarity to the root exemplar as opposed to those bearing less visual similarity (these groups will be respectively referred to as the HS and LS groups for high and low similarity). This procedure yielded 12 pseudowords in the LS group and 8 in the

HS group. This step was undertaken as further insurance that masking was effective in reducing the contribution of visual codes to lexical access. Unexpectedly, in addition to the main phonological effect, a main effect of visual similarity was also found in that more false positive responses were made to the HS group relative to the LS group ($t$ (14) = 5.32, $p$ < .001). In the HS group, the rate of false positive to pseudowords was 28% versus 11% for the controls, and in the LS group, 8% versus 1%. There was no significant interaction.

This result was problematic in that the whole argument for automatic pre-lexical processing was based on the fact that masking was supposed to eliminate the contribution of visual codes by making the rate of false positive responses in the HS and LS groups equal. Before considering these results within a phonological framework, we examined the possibility that the mechanisms underlying the effect might have been mediated visually.

Visual mediation

If pseudoword effects are to be lexically mediated, then one must turn towards theories like that of Glushko's activation synthesis model to explain the effect. This model is part of a class of models referred to as analogy models. According to Glushko (1978), lexical access is mediated through visual codes which activate a cohort of visually similar lexical entries. Pronunciations for nonwords are synthesized on the basis of the phonological properties of the partially activated entries. This model explains why nonwords with consistent neighbourhoods are named faster than those with inconsistent neighbourhoods (e.g., NATE as related to DATE and HATE versus BAVE as related to HAVE and RAVE). Inconsistent neighbourhoods activate words with different pronunciations which in turn delay the production of a pronunciation for the nonword.

This interpretation was later modified by Brown (1987) who found evidence that it is not mere inconsistency that delays pronunciation and word recognition but the frequency with which a word body is associated to a given pronunciation. According to Brown, there is no inhibition from inconsistent pronunciations produced by similarly spelled words. Rather, it is the frequency with which a particular spelling-to-sound correspondence occurs in the language that mediates ease of pronunciation. Thus, contrary to Glushko's predictions, he found that inconsistent words such as HAVE and consistent but unique words such as SOAP (for which there exists no other similarly spelled neighbour thus no inconsistent sound activation) yielded similar naming latencies because word body associations were the same. Word body was defined here as word endings.

There is corroborating evidence that, when reading nonwords, subjects segment letter strings into units larger than single graphemes (letter or letter clusters representing one phoneme) and that the final vowel consonant (VC) unit is critical to nonword pronunciation. For example, Treiman and Zukowski (1988; Treiman, Goswami, & Bruck, 1990) found that subjects place greater importance on final vowel consonant units in reading nonwords.

In order to explain the pseudoword effect obtained in Experiment 1 within an analogy framework (with consideration to the set of findings reported above) consider the following. For a false positive match between the pseudoword foil and the target lexical entry to be visually mediated, one would have to assure there exists a lexical path of activation that explains both the main effect of homophony and visual similarity.

Now, recall that both pseudowords and nonword controls were equated on their visual similarity to other words and to the root exemplar. Given the evidence concerning the weight given to word body associations in nonword processing, it is possible that the pseudowords were associated with a higher number of similar word bodies (final VC units) leading to the root exemplar than the nonword controls.

For example, the pseudoword REEP might activate many words like DEEP, and the resulting phonological activation of these lexical nodes would also spread to words like HEAP (Hillinger, 1980). Eventually, this pattern of activation would lead to the activation of the root exemplar REAP, causing on some trials, a false identification match. In contrast, it is possible that the nonword controls were not visually associated with real words that rhyme with the root word. Thus, the main effect of homophony would be explained on the grounds that by their nature, the pseudoword activates words rhyming with the root exemplar to a greater extent than the control nonword.

If this visual path of activation is correct then one must hypothesize that the main effect of visual similarity between the HS and LS group is due to the HS group activating more lexical entries leading to the root exemplar than the LS group. Consider REEP which is a HS pseudoword and ROAP which is an LS item. According to the diagram drawn in Figure 3, REEP happens to activate more entries leading to the root exemplar than ROAP. This overall increased level of activation in the network might elevate the probability that a false positive match be made in the HS group relative to the LS group.

Several sources of evidence tend to invalidate this interpretation of the

Visual mediation

| High Similarity | Low Similarity |
|---|---|
| Stimulus foil | Stimulus foil |
| **REAP** | **ROAP** |
| cheap | soap |
| heap | |
| leap | /ope/ |
| /eep/ | cope |
| beep | dope |
| creep | grope |
| deep | hope |
| jeep | lope |
| keep | pope |
| peep | scope |
| seep | slope |
| sheep | |
| sleep | Root word |
| steep | **ROPE** |
| sweep | f = 9 |
| weep | |
| Root word | |
| **REEP** | |
| f = 15 | |

Figure 3. Diagram of visual path of target activation based on word body association (f = body association frequency).

pseudoword effect. A computation was made of the number of words whose bodies (final VC units, and related rhyming VC units, for example, LEAP, and the related rhyming word DEEP) were associated to the pseudowords contained in both the HS and LS groups. The computation involved log word frequency (according to Kucera & Francis norms, 1967), and in accordance with Brown's (1987) findings, consideration was given only those words with consistent phonological information. Furthermore, inclusion was limited only to one syllable words whose initial consonant unit included single letters or letter clusters corresponding to a consonant phonemic unit. For example, words like *M*AIN, *GR*AIN, *STR*AIN were all included in the data base related to the pseudoword TRANE. No significant differences between the two groups were found, ($t\,(18) = .17$, $p > .1$) with the HS group having a mean natural log frequency count of 6.39 ($Se = .48$) and the LS group, a mean log frequency count of 6.47 ($Se = .22$).

Furthermore, evidence from a study examining naming latencies to pseudowords shows final VC units not to be a determining factor in phonological effects. McCann & Besner (1987) report a study where naming latencies to pseudowords were shorter than that of control nonwords. Of interest, is the fact that their set of pseudoword and control nonword pairs differed only in initial consonant units. In other words, they shared the same final VC units. (Note that the stimulus pairs were equated on a measure of bigram frequency derived from Mayzner & Tresselt, 1965). Thus, the visual analogy explanation as described above cannot be applied to their results since both pseudowords and control nonwords led to the activation of the same lexical VC units. Still, they found a phonological effect.

Finally, the authors found that orthographic similarity as measured by N affected nonword but not pseudoword naming latencies. These results parallel those previously reported in the literature where N affects nonword but not word naming and lexical decision latencies (Coltheart et al., 1977; Andrews, 1989).[3] Thus it seems that pseudowords enjoyed a status similar to that of words, the cause of which can only be attributed to underlying phonological codes.

In light of these results, there are no grounds to support the analogy explanation. The pseudoword and control nonword stimuli of the present thesis were equated on their similarity to other words and to the root exemplar, and post-hoc analyses reveal that both the LS and HS groups were equated on a measure of word body association. Thus, there is no supporting evidence to explain the pseudoword and visual similarity effects that were obtained in Experiment 1 within an visual analogy framework.

Having discarded the possibility that the homophone and visual similarity effects were mediated by purely visual access processes, the possibility that the effects were phonologically mediated was examined.

Phonological mediation

In light of the above analysis, the results were considered in the context of a model which incorporates both visual and phonological mediation. Although there exist many such dual access models, the verification paradigm discussed by Van Orden (1987, Experiment 3) was judged most appropriate. According to Van Orden,

[3] Note however that when Andrews (1989) examined N as a function of word frequency, a small but significant effect of N was found on naming latencies to low frequency words. Still, this should not substantially modify the core of the argument presented above.

visual similarity effects occur because of a verification stage where the target's orthographic code is compared to that of the phonologically accessed lexical entry. The effect disappears under masking conditions because the visual information is no longer available for spelling checks or verification. This verification model contends that bottom up processing proceeds along a phonological path of activation whereas top down processes operate upon the orthographic representations. The verification loop is used to avoid misidentifications of phonologically ambiguous words.

Additional support for this theory came from an experiment where Van Orden (1987, Experiment 3) contrasted predictions made by the verification model with those of a dual access model, namely the bypass account proposed by Doctor & Coltheart (1980).

According to the bypass account, a direct route between print and lexical access is developed for high frequency words, thus eliminating the need for phonological mediation. Consequently, the higher the frequency, the more likely it is that phonology will be bypassed in favour of direct access, eliminating phonological effects on reading performance for high frequency stimuli. This model is consistent with results in the literature showing that consistency and regularity effects are confined to low frequency words.

In contrast, the verification model contends that the locus of frequency effects is at the verification stage where a spelling check is carried out on the candidate word. The higher the frequency of the lexical entry, the more likely it is that spelling knowledge of the lexical entry is secured and available for the spelling process to be carried out.

These predictions were tested by Van Orden (1987, Experiment 3). Homophone foils were divided into two sets of four frequency groups (from very low, VL, to very high, VH). According to the bypass hypothesis, there should be an effect of frequency on false positive rates such that less errors should be made on the VH frequency homophone foils such as MEET for the category TYPE OF FOOD, relative to VL frequency foils such as PEEK for the category PART OF A MOUNTAIN. In contrast, the verification hypothesis predicts that the effect of frequency will be on the root exemplar, such that less errors should be made on homophone foils whose corresponding root exemplar is of the VH frequency type, and more errors to those whose root exemplar is of the VL frequency type. For example, upon presentation of the category PART OF A HORSE'S BODY, more errors should be made to the homophone foil MAIN, because the root exemplar, MANE, is low in frequency. On the other hand, upon presentation of the category A UNIT OF TIME, less errors should be made to WEAK, because the root exemplar, WEEK, is of high frequency.

Results favoured the verification model. Whereas there was no effect of the homophone foil frequency on false positive rates, the frequency of the corresponding root exemplar affected the rate of responses such that error rates decreased as the frequency of the root exemplar increased (VL = 55%, L = 40%, H = 22%, and VH= 16%).

This evidence suggests that once a lexical entry has been accessed, its spelling is compared to that of the candidate entry. It follows then that the probability of a false match occurring during this stage will be affected by the degree of visual similarity between the two entries. Thus, this model explains the effect of visual similarity obtained in Experiment 1 on the grounds that the more similarity there exists between the stimulus foil and the root exemplar, the more likely it is that detection errors will be overlooked in the spelling check; hence, the higher false positive rate to foils bearing greater visual similarity to the root words relative to those bearing less similarity.

Thus, despite the fact that masking failed to achieve the methodological objectives pursued relative to the masking of visual codes, one can state with a certain amount of confidence that the effect of homophony that was obtained reflects pre-lexical phonological activation. This conclusion is supported both by results described in Van Orden (1987, Van Orden et al., 1988), and by an inability to fit the data within an analogy framework. Note, however, that the latter conclusion was based on null findings reached on a post-hoc basis. A more direct test would involve a systematic manipulation of CV units between groups of pseudoword letters strings.

This brings up the issue on the appropriateness of visual control measures used in the literature so far. Models of parallel distributed processing (PDP) add an interesting perspective to this issue. According to Seidenberg & McClelland, PDP models capture the complexity of the relationships between different linguistic features interwoven in the language by representing the statistical relationships through a distributed network of activation. Accordingly, Seidenberg & McClelland (1989) were able to implement a model that accounted for a lot of the empirical phenomena reported in the literature. Of interest, however, is their account of pseudoword effects. According to these authors, pseudowords are faster to name and longer to reject as nonwords because they are more wordlike than nonword controls.

To support this, they ran a set of pseudowords used by authors who claimed to have found support for the phonological hypothesis (McCann et al., 1988) in the simulation. They found, as predicted, that the model performed better with the pseudowords than with the controls (as reflected by orthographic and phonological error scores). They then constructed another set of pseudoword and nonword letter strings on which the model performed equally well (equal error scores). This new set of stimuli was referred to as the even set while McCann et al.'s was referred to as the uneven set. When they tested subjects on these two sets of stimuli, they found a pseudoword effect with the uneven set, but failed to find a pseudoword effect on the even set. They thus attributed the pseudoword effect found by McCann & Besner to be an artifact of visual similarity and lexicality (see however, Besner, Twilley, McCann, & Seergobin, 1990 for alternative interpretation of these results; and Seidenberg & McClelland's subsequent reply, 1990).

While there are still problems with the model's implementation (and other ones like it), it is interesting to note that two different sets of pseudowords caused subjects to perform differently. Given the importance of the visual similarity factor in the investigation of phonological recoding and the pseudoword effect, it might be interesting to test different control measures of visual similarity against the model's performance and empirical data. For example, the set of pseudowords used in this thesis could be submitted to the simulation in order to examine whether the model supports the assertion that the stimuli used here were equally wordlike. In any case, this is an ongoing issue that needs pursuing before clear conclusions can be drawn about the nature of pseudoword effects.

Before closing, the implications of the results concerning the persistence of a visual effect under masking conditions must be addressed. Indeed, this effect is perplexing. In Van Orden's experiment (1987), subjects were reported as having identified most of the exemplars and very few of the nonmembers. Under these conditions, visual effects were eliminated. In the present experiment, nonmembers were correctly identified 40% of the time. While members were identified in a significantly greater proportion, 60%, they were still not identified on *many* of the presentations. The fact that a third type of trial and response was incorporated in the paradigm may have been a determining factor of this outcome. Subjects were encouraged to press the "YES" and "NO" keys *only* upon identification of words. They were otherwise told to press the "?" key. Thus in a way, subjects were encouraged to use a very conservative strategy. It may be then that in the present experiment, they relied on a greater amount of evidence before selecting a response. That is, on the whole, they may have set a much more conservative decision criterion than Van Orden's subjects. Although this would not differentially affect their responses to different types of trials, it would affect the amount of evidence required for response selection. As a consequence, this would have the effect of allowing more visual information to accrue before a decision was made, and hence the visual effect.

Nevertheless, the fact that phonological effects persisted despite very poor viewing conditions is consistent with the notion of automatic activation whereby phonological codes were activated soon enough to exert an influence on semantic decisions. The percentage of phonologically ambiguous stimuli included in these experiments, however, was very low. It might be useful therefore in the future to include a condition containing a high percentage of pseudowords to corroborate the notion of automatic activation (in a manner similar to that of Davelaar et al., 1978; McQuade, 1981). If subjects have control over their processing strategy, then one might expect phonological effects to disappear in the high homophone set condition. On the other hand, the persistence of phonological effects under these conditions would provide further support to the notion that automatic processes underlie the effect observed in Experiment 1 of the present thesis.

In closing, the results support the view that lexical access is phonologically mediated for skilled readers of English and that this mediation is probably automatic. Although the experiments were not designed to address the issues related to the process by which the phonological information was extracted (whether by application of rules or through computational analyses), the view that phonological properties of printed material are extracted early enough to influence the reading process gained some support. The experimental paradigm used here (which was borrowed from Van Orden, 1987) seems to be a promising avenue for the investigation of other related issues such as language specific effects, reading skill, and automaticity providing that the stimuli conform to the orthographic patterns contained in the targeted language.

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## Appendix A

List of homophone and control targets used in Preliminary study

| CATEGORY NAME | HOM | CTRL | ROOT |
|---|---|---|---|
| A FEATURE OF AN OCEAN SHORE | BEECH | BENCH | beach |
| A KITCHEN UTENSIL | BOLL | BOIL | bowl |
| A WILD ANIMAL | BORE | BORN | boar |
| A SMALL STREAM | CREAK | CHEEK | creek |
| A DEER | DOUGH | DOUBT | doe |
| PART OF A PERSON'S FACE | KNOWS | SNOBS | nose |
| AN ANCIENT MUSICAL INSTRUMENT | LOOT | LOST | lute |
| A SERVANT | MADE | MAIN | maid |
| TYPE OF FOOD | MEET | MELT | meat |
| A FEATURE OF A PERSON'S ABDOMEN | NAVAL | NOVEL | navel |
| A MEMBER OF A CONVENT | NONE | NINE | nun |
| PART OF A MOUNTAIN | PEEK | PECK | peak |
| A BIBLICAL RELIGIOUS LEADER | PROFIT | PROTEST | prophet |
| PART OF A HORSE'S BRIDLE | RAIN | RUIN | rein |
| A FLOWER | ROWS | ROBS | rose |
| PART OF A DRESS | SEEM | SLAM | seam |
| A BREAKFAST FOOD | SERIAL | VERBAL | cereal |
| TYPE OF HOTEL ROOM | SWEET | SHEET | suite |
| ORGANIZED GROUP OF PEOPLE | TEEM | TERM | team |
| SOMETHING CAUSED BY GRAVITY | WAIT | WRIT | weight |

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Note. HOM = Homophones CTRL = Control words ROOT = Root Homophone

# Appendix B

List of member, monmember, and nonword experimental targets.

| CATEGORY NAME | M | N | X | X |
|---|---|---|---|---|
| A CRIMINAL OFFENSE | RAPE | SPOT | DRAM | SWOD |
| A DOMESTIC ANIMAL | COW | BAR | TUZ | VED |
| A DOMESTIC ANIMAL | DOG | GYM | DAR | FIP |
| A DOMESTIC ANIMAL | PIG | VAN | DAT | TAL |
| A FEATURE OF A BUILDING | DOOR | LIME | BAVE | GOTH |
| A FEATURE OF A BUILDING | ROOM | LUNG | BANT | HAGE |
| A FEATURE OF A BUILDING | WALL | MILK | KELP | YOLE |
| A KIND OF BIRD | CROW | DATE | BAFT | GODE |
| A KIND OF BIRD | JAY | GUN | CAG | RIT |
| A LARGE BODY OF WATER | LAKE | HOOK | BOLB | FRIP |
| A TIME OF DAY | NOON | CAMP | JOAL | SARE |
| AN ALCOHOLIC BEVERAGE | BEER | CLAM | DODE | FLAD |
| AN ALCOHOLIC BEVERAGE | RUM | COD | HAR | JUN |
| AN ALCOHOLIC BEVERAGE | RYE | FIG | HIN | LAN |
| AN ALCOHOLIC BEVERAGE | WINE | PLUM | MIDE | WULL |
| AN ARTICLE OF CLOTHING | COAT | CLUB | BELK | JATE |
| AN ARTICLE OF CLOTHING | HAT | CAR | LOR | GAT |
| AN ARTICLE OF CLOTHING | VEST | JEEP | JILD | SOLT |
| PART OF THE HUMAN BODY | BRAIN | PEARL | GLAVE | CRADE |
| PART OF THE HUMAN BODY | FOOT | JADE | DOAN | FAND |
| PART OF THE HUMAN BODY | HEAD | PINE | GARK | GOVE |
| PART OF THE HUMAN BODY | KNEE | TOAD | SALN | SHUB |
| PART OF THE HUMAN BODY | SKIN | BARK | MOOK | RAME |
| THE NAME OF A COLOUR | GREEN | DEATH | DRACK | SLARE |
| THE NAME OF A COLOUR | RED | FOX | ONK | SOP |
| THE OPPOSITE OF NARROW | BROAD | SHIRT | BRACK | CHACK |
| THE OPPOSITE OF SHALLOW | DEEP | HOME | BOSE | GRUN |
| TYPE OF BOAT | RAFT | BOOK | BELD | GOME |
| TYPE OF BOAT | SHIP | ROCK | NUCK | SLET |
| TYPE OF CONTAINER | CUP | BUS | PED | SEP |
| TYPE OF CONTAINER | VASE | WILD | BUKE | SPOG |
| TYPE OF DETERGENT | SOAP | TANK | TANE | TINK |
| TYPE OF EMOTION | FEAR | PINK | TORD | WACE |
| TYPE OF EMOTION | JOY | LAW | ITE | PLO |
| TYPE OF FABRIC | LACE | GOLF | BORT | GOAN |
| TYPE OF FABRIC | WOOL | PALM | BOST | TRAS |
| TYPE OF FABRIC | YARN | SEAT | VOND | WEGE |
| TYPE OF FURNITURE | DESK | CRAB | CIVE | FIDE |
| TYPE OF FURNITURE | LAMP | HAND | TRIN | WOLN |
| TYPE OF TRANSPORTATION | TRAIN | CROWN | BLOSS | BRAIT |

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Note. M = Member N = Nonmember X = Nonword

## Appendix C

List of Nonmember and Nonword targets:
Calibration phase, Part I

| CATEGORY NAME | N | X |
|---|---|---|
| TYPE OF DISEASE | ADULT | ALTAM |
| A PIECE OF FURNITURE | VALUE | BLICE |
| AN ARTICLE OF CLOTHING | ACIDS | BATER |
| A KIND OF BIRD | BUSH | VOME |
| A PIECE OF FURNITURE | CUT | COE |
| AN ARTICLE OF CLOTHING | SCREW | FRASH |
| AN ARTICLE OF CLOTHING | BEANS | BLANE |
| A FOUR-FOOTED ANIMAL | FLOCK | DROKE |
| A WILD ANIMAL | MEDAL | SPAIL |
| THE NAME OF A COLOUR | MOTION | BATION |
| TYPE OF DWELLING | NIGHT | CLEAD |
| A FLOWER | LAVA | ROAK |
| A FLOWER | ARDOR | ASPET |
| A CRIMINAL OFFENSE | BONUS | DERSE |
| A KIND OF BIRD | FILLER | PATTER |
| A BEVERAGE | BEEP | BYME |
| A KIND OF FISH | ARMPIT | BLOMER |
| A SEA CREATURE | STUNT | BRATE |
| A KIND OF BIRD | BARON | GLEAK |
| TYPE OF BOAT | SQUAW | PLIME |
| A KIND OF FISH | TOFU | BOFA |
| TYPE OF FABRIC | BLOWER | BRAMER |
| TYPE OF FABRIC | PUTTY | BREEK |
| A KIND OF FISH | GREED | SLAIR |
| TYPE OF FABRIC | GAZE | FEEP |
| AN ARTICLE OF CLOTHING | RAMPS | BONCH |
| A BEVERAGE | SECRET | MACRET |
| TYPE OF DISEASE | FORKS | BETCH |
| TYPE OF FRUIT | BLITZ | PLAIM |
| THE NAME OF A COLOUR | LARGE | SLEED |
| A PIECE OF JEWELRY | BOND | VEEN |
| THE NAME OF A COLOUR | CLASS | STURT |
| A BEVERAGE | CLIFF | BLAIT |
| TYPE OF FABRIC | INSTANT | INSPALT |
| A CRIMINAL OFFENSE | NIECE | FREET |
| THE NAME OF A COLOUR | CARPET | STROOM |
| A CRIMINAL OFFENSE | GRIEF | PLOKE |
| AN ARTICLE OF CLOTHING | SEEDS | SLAKE |
| TYPE OF FABRIC | RELIC | ADELT |
| TYPE OF FUEL | KEY | ZIT |

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Note. N = Nonmember X = Nonword

## Appendix D

List of member, nonmember, and nonword targets:
Calibration phase, part II

| CATEGORY NAME | M | N | X |
|---|---|---|---|
| A BEVERAGE | WATER | ORDER | MIBLE |
| A KIND OF BIRD | EAGLE | CORAL | ANLET |
| A KIND OF FISH | PERCH | FAIRY | BORAD |
| A KIND OF FISH | TROUT | STAMP | SCOLE |
| A PIECE OF FURNITURE | COUCH | NERVE | FRIZE |
| A PIECE OF FURNITURE | SOFA | GALA | FINT |
| A WILD ANIMAL | LION | RAIL | DAUL |
| AN ARTICLE OF CLOTHING | DRESS | BIRTH | TRUDE |
| THE NAME OF A COLOUR | BROWN | RANGE | SWAPT |
| TYPE OF BOAT | CANOE | TUNIC | THUDE |
| TYPE OF DISEASE | COLD | FINE | YOTE |
| TYPE OF DWELLING | HUT | DOT | FIE |
| TYPE OF DWELLING | IGLOO | TRIAD | TREAN |
| TYPE OF DWELLING | TENT | BOSS | BLID |
| TYPE OF FABRIC | RAYON | ALTAR | COBAL |
| TYPE OF FABRIC | SATIN | TONIC | RELIB |
| TYPE OF FLOWER | LILAC | INLET | BANIC |
| TYPE OF FLOWER | TULIP | WITCH | PROOM |
| TYPE OF FRUIT | APPLE | RESIN | FARON |
| TYPE OF FUEL | DIESEL | SPROUT | PREAM |

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Note. M = Member N = Nonmember X = Nonword

# Appendix E

## List of pseudoword and control targets used in Experiment 1

| CATEGORY NAME | PSEUDOWORD | N | CONTROL | N |
|---|---|---|---|---|
| TYPE OF FOOD | BEAF | 10 | BEEL | 11 |
| TYPE OF TRANSPORTATION | BOTE | 12 | BOME | 10 |
| TO MANAGE | COAP | 9 | COOM | 11 |
| PROFOUND | DEAP | 10 | DEEF | 8 |
| PART OF A TELEPHONE | DILE | 16 | DIPE | 12 |
| A SOURCE OF HEAT | FLAIM | 3 | FLAIT | 3 |
| A SMALL AMOUNT | FUE | 10 | FUD | 10 |
| A FOUR-FOOTED ANIMAL | GOTE | 9 | GOKE | 8 |
| THE NAME OF A COLOUR | GREAN | 4 | GREEL | 6 |
| ENTHUSIASTIC | KEAN | 8 | KEEF | 5 |
| ADJACENT | NEER | 9 | NEAM | 6 |
| A SHORT MESSAGE | NOAT | 6 | NOUT | 6 |
| TO GATHER | REEP | 12 | REAN | 13 |
| USED FOR PULLING | ROAP | 5 | ROOR | 8 |
| TYPE OF DETERGENT | SOPE | 10 | SOVE | 11 |
| TO IMMERSE IN A LIQUID | SOKE | 9 | SOTE | 11 |
| A YOUNG PERSON | TEAN | 12 | TEEP | 11 |
| TYPE OF TRANSPORTATION | TRANE | 3 | TRAPE | 5 |
| A SPECIAL FAVOUR | TREET | 4 | TREAL | 3 |
| A JUDICIAL PROCESS | TRILE | 5 | TRIME | 8 |

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Note. N = N variable according to Colthearts' orthographic legality measure.

# Appendix F

Percentage of YES, NO, and ? responses as a function of stimuli in Experiment 1

| | RESPONSE | | |
|---|---|---|---|
| STIMULUS | YES | NO | ? |
| Pseudowords | 18 | 3 | 79 |
| Nonword Controls | 4 | 5 | 91 |
| Members | 61 | 2 | 37 |
| Nonmembers | 2 | 41 | 57 |
| Nonwords | 1 | 4 | 95 |

# Appendix G

## List of pseudoword and control targets used in Experiment 2

| CATEGORY NAME | PSEUDOWORD | N | CONTROL | N |
|---|---|---|---|---|
| TYPE OF MINOR INJURY | BROOZE | 1 | BREALE | 0 |
| ELECTRICAL ACCESSORY | KABEL | 1 | VABEL | 1 |
| A SOURCE OF LIGHT | KANDEL | 0 | FANDEL | 0 |
| A MUSICAL GROUP | KWYRE | 0 | KEARE | 0 |
| A GEOMETRIC FIGURE | SIRKUL | 0 | PIRAIL | 0 |
| PART OF A SHIRT | KUPH | 0 | WUTH | 2 |
| THE RESULT OF AN ACTION | EPHECT | 0 | ESHECT | 0 |
| TYPE OF UTENSIL | NIPHE | 1 | NISHE | 1 |
| WHAT STUDENTS DO | LURNE | 0 | LOINE | 1 |
| A STAGE OF DEVELOPMENT | FAYZE | 0 | DAIPE | 0 |
| A PLAYING CARD | KWENE | 0 | FRENE | 0 |
| A STATE OF SILENCE | KWIET | 0 | DRIET | 4 |
| SOMEWHAT - ALMOST | KWYTE | 0 | SAITE | 4 |
| TYPE OF CITATION | KWOAT | 0 | DROIT | 0 |
| COMMERCIAL EVENT | SAYL | 1 | SARL | 4 |
| SOMETHING USED IN CARPENTRY | SKROO | 0 | SHRID | 1 |
| TYPE OF DEMAND | KLAME | 2 | PLAME | 5 |
| A JUDICIAL PROCESS | TRYEL | 0 | TROOL | 2 |
| A STATE OF MIND | WURIE | 0 | WARCH | 2 |
| TYPE OF VEHICLE | KARZ | 1 | VART | 9 |

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Note. N = N variable according to Coltheart's orthographic measure.

# Appendix H

**Percentage of YES, NO, and ? responses as a function of stimuli in Experiment 2**

| | RESPONSE | | |
|---|---|---|---|
| STIMULUS | YES | NO | ? |
| Pseudowords | 0 | 4 | 96 |
| Nonword Controls | 0 | 6 | 94 |
| Members | 77 | 4 | 19 |
| Nonmembers | 2 | 56 | 42 |
| Nonwords | 1 | 8 | 91 |