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Polysemy effects in naming low-frequency irregular words:

A rare semantic advantage?

by

Brenda J. Baird, B. A.

A thesis submitted to

the Faculty of Graduate Studies and Research

in partial fulfilment of

the requirements for the degree of

Master of Arts

Department of Psychology

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Chair

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Carleton University
August 1997

Abstract

Two experiments investigated the effects of polysemy (number of meanings) and regularity (adherence to a rule-based phonology) on phonological coding. Regular and irregular low-frequency words were presented in both online and delayed naming tasks. Main effects of polysemy and regularity, and an interaction between these two variables were observed in the online naming condition only. Polysemy appears to resolve phonological conflict for words having irregular spelling patterns. The relevance of these effects are discussed in terms of incorporating a semantic role into current models of phonological coding.

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Introduction

In tasks such as word naming, the recognition process is complicated by the fact that orthographic input codes (spelling patterns) must be mapped onto their corresponding phonological output codes (sound patterns). Readers must therefore rely on spelling-to-sound correspondences to sound a word out, activating phonological segments and integrating them to construct a phonological code. Most theorists have attempted to characterize the nature of orthographic and phonological representations and to describe how orthography is mapped onto phonology (e.g., Borowsky & Masson, 1996; Seidenberg & McClelland, 1989). Although many theorists incorporate a semantic module into their models, a general consensus regarding how semantics may impact on phonological coding is lacking. The purpose of the present research was to examine the possible role of semantics in phonological coding.

Background Research and Theories

Two classes of models currently dominate the word recognition literature: dual-route and parallel distributed processing (PDP). Both of these classes of models have been constructed around two variables known to influence phonological coding: frequency and regularity. The frequency effect is a ubiquitous finding in the word recognition literature (e.g., Forster & Chambers, 1973; Scarborough, Cortese, & Scarborough, 1977; Taft, 1979; Whaley, 1978). Response latencies are significantly faster to written words that frequently occur in the language (high-frequency words) than to words that occur less frequently (low-frequency words).

Orthographic regularity refers to the distinction between a regular word for which

phonology can be correctly derived solely from its spelling pattern, and an irregular word for which phonology depends on information accessed by lexical means. Regular words are made up of orthographic units (e.g., graphemes) that can be converted into sound (e.g., phonemes) by virtue of a rule-based translation. For example, words such as *mini* and *lint* can be converted into sound by following a regular, grapheme-to-phoneme conversion (GPC) process. In contrast, the letter string *pint* is irregular as it does not preserve a consistent mapping between orthography to phonology. Regularity, therefore, is defined by an adherence to a consistent pattern for converting print to sound.

Research has shown that regularity and frequency interact (Paap & Noel, 1991; Seidenberg, Waters, Barnes, & Tanenhaus, 1984; Taraban & McClelland, 1987). High-frequency words are named quickly regardless of regularity, whereas low-frequency irregular words are pronounced more slowly than low-frequency regular words. As discussed below, the interaction between regularity and frequency can be explained using either a dual-route or a connectionist model..

Dual-route Models. Dual-route theorists (e.g., Baluch & Besner, 1991; Coltheart, Besner, Jonassen, & Davelaar, 1979; Coltheart, Curtis, Atkins, & Haller, 1993; Paap & Noel, 1991) suggest that word recognition takes place along two qualitatively different processing routines: a lexical route involving addressed, whole-word phonology, and a nonlexical route involving GPC rules. Output from both processes converges in a common buffer where decisional mechanisms act to resolve the final output. Processing along the nonlexical route is assumed to be a product of the GPC process which translates orthographic sequences into their corresponding phonological patterns. This form of

processing is commonly referred to as assembled phonology (McCann & Besner, 1987).

The dissociation between the lexical and nonlexical routes becomes clear when one considers how irregular words are phonologically coded. Because the nonlexical route relies on a rule-based system, irregular words processed along this route result in pronunciation errors. As such, irregular words cannot be correctly pronounced in the way that orthographic-to-phonological (O-P) rules would dictate. In contrast, processing along the lexical route accesses whole-word entries from which phonology can be correctly derived.

In the dual-route model, high-frequency words are named faster than low-frequency words because retrieved phonology along the lexical route is sensitive to past encounters with a word. Because high-frequency words are encountered more often than low-frequency words, a processing benefit occurs when accessing whole-word phonology for a high-frequency word. Assembled phonology along the nonlexical route is insensitive to frequency, but even though this process is usually slower than addressed phonology, it is no slower than retrieved phonology along the lexical route for a low-frequency word. In sum, the lexical route will process words as a function of frequency; high-frequency words being accessed rapidly relative to the slow activation of low-frequency words. Accordingly, the nonlexical route may have little influence on deriving phonology for high-frequency words.

To account for the frequency by regularity interaction, dual-routine theorists suggest that overlapping responses from the addressed and the assembled routes may create interference during the decision-synthesis stage. Given that two processing pathways are

channelled into one output buffer, a phonological response requires a synthesis between the two routes. Regular words do not produce interference because the outputs from the lexical and nonlexical routes produce identical phonologies. For irregular words however, the lexical and nonlexical routes produce different phonological codes: if the codes from these pathways overlap in the output buffer, one based on general GPC rules, and the other on word-specific retrieval, two incompatible responses for pronunciation are offered. Because the two routes provide conflicting information, pronunciation is slowed. Because low-frequency words take longer to access along the addressed route than high-frequency words, the assembly process "catches up" to the addressed process and both pathways feed into the buffer simultaneously. Competition in the output buffer, therefore, only arises when a word is low enough in frequency that an addressed process produces a correct response at approximately the same time that an assembly process is producing an incorrect one. Because a naming response can only be successfully executed when the phonological representation in the output buffer is clearly defined, competing representations in the buffer produce noise in the system (Paap & Noel, 1991). The degree of overlap between two different codes determines the amount of interference, or noise, in the output buffer, and noise must be resolved for successful response execution. Thus, the frequency by regularity interaction arises because of competition between two processes for converting spelling to sound. This conflict is most severe for low-frequency, irregular words because two alternatives for pronunciation are offered: one (correct) from the lexical route and one (incorrect) from the nonlexical route.

Parallel Distributed Processing Models. Connectionist, or parallel distributed

processing models (PDP), are based on one processing system and, therefore, stand in stark contrast to dual-route models. In PDP models, lexical knowledge is represented in weights that reflect the strength of connections, or links, between sets of processing units (Seidenberg & McClelland, 1989). Typically, a word is represented by the summed pattern of activation across orthographic and phonological processing units. A known word is instantiated by evoking a pattern of activation operationalized as the strength among connection weights across processing units. The model developed by Seidenberg and McClelland is a learning model that uses back propagation to resolve noise within the various layers by using hidden units. These units adjust weights among connections to eventually arrive at the correct output. This settling process is determined by the difference between output generated by the model and the correct target output, a difference referred to as phonological and orthographic error scores. Reducing these differences increases the probability of a correct response. Specifically, frequent exposure to an item in the training corpus decreases the phonological and orthographic error scores, and (presumably) the time needed to settle on a response. While most researchers use naming latency to determine processing time, Seidenberg and McClelland (1989) used accuracy (based on the phonological error score) to approximate latency data. Others, such as Borowsky and Masson (1996) have approximated latency data by using the amount of processing cycles their model needed to settle the connections between processing units.

Of particular interest is the PDP model's somewhat slower, more error-prone performance on low-frequency, irregular words, thus replicating the data obtained with

humans. Proponents of the PDP model explain the frequency by regularity interaction based on the model's previous learning experience. Low-frequency irregular words have unstable orthographic-to-phonological connections due to their relatively infrequent and inconsistent mappings. Such inconsistencies produce larger error scores, thus resulting in an incorrect output response. The frequency by regularity interaction, according to this model, arises because many phonological features are activated for low-frequency, irregular words: the model, and presumably humans, lacks the experience necessary to resolve, or to settle the connection weights of these words. In agreement with the outcome predicted by dual-route models, response latencies to low-frequency, irregular words are slower than low-frequency regular words as a result of such inconsistent phonological patterns.

Role of Semantics in Phonological Coding

The dual-route notion of two mechanisms is flexible and offers explanatory power for the frequency by regularity interaction, but it lacks an explicit explanation for the role of semantics in phonological coding. To date, dual-route theorists have not incorporated word meaning, or semantics, into their framework.

Some PDP theorists (e.g., Plaut, McClelland, Seidenberg, & Patterson, 1995) have incorporated a semantic layer into their models, but they have not explicitly described how semantics may influence phonological coding. It may be that given orthographic-to-phonological conflict, semantics offers additional information that expedites the conversion from print to sound. When processing results in two different pronunciations, a semantic layer may be weighted more heavily than other variables resulting in faster

naming latencies for words having multiple meanings. Because the O-P connection is inconsistent for irregular words, processing may be directed toward a more consistent processing source, specifically, toward the mappings from semantics to phonology. In this way multiple meanings impact on phonology by contributing more processing weight to the computation of a naming response.

The present research was motivated by the hypothesis that multiple meanings (i.e., polysemy) may facilitate the conversion of orthography-to-phonology, particularly for low-frequency, irregular words. As discussed above, low-frequency, irregular words are named more slowly than are words of higher frequency and with consistent orthographies, thus defining the well-established frequency by regularity interaction. If semantics plays a role in word naming by resolving the unstable connection between orthography and phonology, this facilitation should be reflected in decreased naming latency and increased accuracy for low-frequency, irregular words having multiple meanings. Semantic processes may not be engaged to such an extent for regular words, or for those of high-frequency, simply because the processing system does not need to access semantic information in determining a correct pronunciation.

In sum, semantics may assist in resolving inconsistencies within the word-processing system. On this view, because both meanings of a polysemous word are associated with a single phonology, semantics may facilitate the processes necessary to derive the correct pronunciation as compared to a nonpolysemous word. Activating several semantic representations may impact on phonological processing by providing a richer source of information than one meaning would offer.

Evidence for polysemy effects

Lexical decision. Most researchers investigating the role of polysemy in word recognition have used lexical decision tasks. For example, Rubenstein, Garfield, and Millikan (1970) found that lexical decision latencies were significantly faster to words having many meanings (polysemous) relative to words having only one meaning (nonpolysemous), and this effect was independent of word frequency. These findings, however, were criticized by Clark (1973) who suggested that Rubenstein et al.'s effects were confined to their particular stimulus set and therefore, the results are not generalizeable. Clark's argument was substantiated by Forster and Bednall's (1976) failure to replicate the polysemy effect. These authors measured lexical decision latencies to high- and low-frequency words that had one, or more than one meaning. Although a main effect of frequency emerged, they failed to find either a significant main effect of polysemy or an interaction between frequency and polysemy.

Jastrzembski (1981) proposed that failure to obtain significant polysemy effects lie in the different criteria for determining polysemy. Specifically, whereas previous researchers defined polysemy on the basis of two versus one meaning, Jastrzembski (1981) suggested a more powerful test of polysemy based on many versus few meanings. Using this criterion, Jastrzembski reported significant main effects of frequency and polysemy in lexical decision, and also a significant interaction between polysemy and frequency: polysemy effects were greater for low-frequency words than for high-frequency words. However, Gernsbacher (1984), using the number of meanings in an unabridged dictionary as the polysemy metric, failed to replicate Jastrzembski's interaction and reported

experiential familiarity as the variable affecting lexical decision time, not polysemy.

Gernsbacher maintained that the inconsistent interaction between word frequency and number of word meanings was due to the inconsistencies in defining polysemy. Words that were more familiar were processed faster regardless of how many meanings they had. As a result of such criticism, Gernsbacher advanced the investigation of polysemy effects by teasing out possible confounds such as item familiarity.

Millis and Button (1989) also reported a significant polysemy effect in lexical decision; however, they determined that obtaining the polysemy effect largely depends on how polysemy is measured. When participants were required to generate all meanings for every word presented (accessible polysemy) the effect emerged. However, when polysemy was based on the first meaning that came to mind, and summed across participants, the effect barely reached significance. Millis and Button suggested that the first meaning-metric is an insensitive measure of polysemy because it does not adequately reflect all meanings that a participant can access in memory. In accord with Gernsbacher (1984), Millis and Button established that using the number of dictionary definitions as the sole indicator of polysemy is not a valid measure. However, because Millis and Button equated words on overall mean frequency, the differential effects of frequency (high, low) were not analyzed.

Whether polysemy influences lexical decision performance may also depend on strategic factors that influence the level of processing necessary to determine an item's lexical status. Borowsky and Masson (1996) found a polysemy advantage for words in a lexical decision task when orthographically legal nonwords were used. The size of the polysemy effect was reduced when orthographically illegal nonwords were used. Illegal

nonwords are letter strings, such as *grhent*, for which word status can be readily determined from the spelling pattern. Orthographically legal nonwords, such as *blape*, pose difficulty for the lexical word/nonword distinction because participants are unable to base their decision solely on the orthographic structure of the target letter string. Because a legal nonword looks like a word, participants needed better clues than orthography (i.e., meaning or phonology) to determine whether or not a letter string is a word. Borowsky and Masson also showed that the usual advantage for words over nonwords reappeared when illegal nonwords were part of the stimulus set. Relying on orthographic structure alone enabled participants to discriminate words from nonwords. When pseudowords resembling real words were included in the target set (e.g., *fleak*), semantics may have provided additional information to the word/nonword decision. The size of the polysemy effect was significantly reduced when illegal nonwords were included in the stimulus set. The implication is that semantics aided in distinguishing words from nonwords when the distinction could not be made based on spelling alone.

In a similar vein, Kellas, Ferraro, and Simpson (1988) demonstrated that processing was less attention demanding for polysemous words than for nonpolysemous words. Using lexical decision and a secondary probe task these authors concluded that multiple semantic representations facilitated early encoding processes. Their data indicated that words with multiple meanings resulted in better performance on the secondary task than did words having one meaning. The relevant implication of this study is that words having multiple meanings reach an activation threshold faster than words having only one meaning. This processing advantage was revealed in faster lexical decision latencies to

multiple-meaning words, allowing attentional resources to be allocated to the secondary task.

Evidence for polysemy effects

Naming. Although Borowsky and Masson (1996) reported a polysemy advantage in lexical decision they did not find polysemy effects in naming using the same items. Borowsky and Masson, however, did not analyze word frequency, nor did they manipulate orthographic regularity. As a result, any differential effects of meaning on low- and high-frequency words, and on regular and irregular words, was not investigated. Also, many of the low-frequency polysemous words in their word corpus were regular. If phonology is derived from semantics, then any empirical manipulations should include variables such as orthographic regularity and word-frequency in an attempt to maximize the semantic effect.

Hino and Lupker (1996) examined number of meanings and word frequency in both lexical decision and naming tasks. Results from the lexical decision task showed equivalent effects of polysemy for high- and low-frequency words, whereas results from the naming task showed an interaction between polysemy and frequency: polysemy effects were limited to low-frequency words. Hino and Lupker argued that the interactive effect of polysemy and frequency emerges during naming due to the nature of the task, which requires the retrieval of phonological representations. Using orthographic clues in the lexical decision task, participants were able to process high- and low-frequency words equally well. However, when the task involved retrieving phonological representations, the connections between orthographic and phonological units were stronger for high-frequency words. Relative to processing low-frequency words, the speed of generating a

phonological code for high-frequency words does not allow enough time for the semantic system to influence processing. In contrast, the slower retrieval of phonology for low-frequency words would enable semantics to exert its influence.

One aspect of polysemy research that becomes clear from examining the literature is the consistent failure of researchers to manipulate orthographic regularity (regular, irregular) when using the naming task. An exception is Strain, Patterson, and Seidenberg (1995) who manipulated word imageability (concrete versus abstract semantic representations) using low-frequency, irregular words. One of the few studies to obtain a significant semantic effect in naming (see also Hino & Lupker, 1996), these authors found an imageability advantage for low-frequency, irregular words. Words with less imageability, such as scarce, were named slower than words with more imageability, such as soot. The importance of the imageability effect is that the role of semantics is clearly implicated. Strain et al. suggested that semantics has the largest impact on words that are subject to noisy orthographic-to-phonological translation processes.

Present Research

The purpose of the present research was to investigate a role of semantics in phonological coding. To this end, experimental manipulations were designed to detect fragile or inconsistent orthographic-to-phonological mappings. If evidence is obtained to establish that low-frequency, irregular words with multiple meanings are recognized faster than low-frequency irregular words with only one meaning, it could be suggested that meaning plays a role in the recognition process. On this view, polysemy may facilitate naming by allowing the transcoding from orthography to phonology to be completed

earlier. As stated by Van Orden, Johnston, and Hale (1988), it is difficult to avoid the notion that phonology plays a role in reading text for meaning. The present research, however, is focused on determining the semantic role in isolated word recognition.

This study is unique in that it combined word regularity with semantic ambiguity, yet using only low-frequency words. It was expected that using this class of words would maximize any semantic effects. Because this research is concerned with phonological processing, the naming task was chosen over lexical decision because naming requires a phonological response. Two naming paradigms were used: online and delayed.

Online Naming. In the online naming task, a participant is required to pronounce a word aloud as soon as it appears on a monitor. As such, participants cannot rely solely on the orthographic structure of a word when making their response: naming results from mapping orthography to phonology. Manipulating regularity within low-frequency words should allow semantics to exert a facilitory influence on irregular, low-frequency words. As this class of words is highly susceptible to slow orthography-to-phonology conversions, a polysemy by regularity interaction is predicted, such that naming will be facilitated for polysemous, irregular words.

The prediction of decreased latencies for words having multiple meanings was based on the assumption that semantics would "clean-up" any noise in the system by exerting more processing influence. Also, as the naming task implicitly relies on orthographic-to-phonological conversions, response decisions must be based on this factor. Accordingly, errors were expected to be fewer for polysemous relative to nonpolysemous words. Furthermore, it was believed that the failure of most studies to obtain a significant

polysemy advantage in the naming task may be a consequence of failing to manipulate frequency (high-low) and regularity. The present study addresses this problem.

Delayed Naming. In naming, a response may reflect several aspects of processing: (a) lexical access, (b) mapping the phonological representation to an output, and (c) the actual output. One way to partial out the effects of processes (b) and (c) is to use a delayed naming task. Balota and Chumbley (1985) attempted to tease apart production effects from recognition effects by implementing such a task. In this task participants must wait for a cue before initiating a response. If a response is delayed subsequent to lexical access then any remaining effects could be a result of phonological production rather than of lexical access per se.

The delayed naming condition was added to determine whether the observed effects in online naming were due to speech production. If orthographic-to-phonological recoding is sensitive to multiple meanings, then any contaminating effects of production obtained from the on-line task should be eliminated. If a post-lexical production variable has no impact on the results obtained from online naming, then a polysemy advantage should not result when production is delayed. If, however, speech output is sensitive to semantics then delayed naming latencies should be faster for polysemous words than nonpolysemous words. Any effect of polysemy would suggest an advantage at this production stage. In addition, any contribution of orthographic-to-phonological conversions to speech output would be reflected in differential naming times for regular and irregular words.

The critical aspect of delayed naming is to ensure that lexical processing has been completed before the delayed response is executed. Accordingly, a conservative delay

interval of 1500 ms (see Herdman, LeFevre, & Greenham, 1994) was implemented to satisfy this concern. Target items were removed from the screen prior to the presentation of the signal-to-respond so that reprocessing an item was not possible. Although repetition effects are a possible confound when including the same items in both immediate and delayed presentation formats, Herdman et al. reported null effects of repetition using the same repeated format. In light of Herdman et al.'s findings, all participants were required to perform the delayed task after the online naming task. Results obtained from the manipulation of on-line and delayed naming will aid in ascertaining a locus for the semantic influence in phonological production.

Method

Participants

Thirty-two undergraduate students participated in the present experiment. Participants were randomly chosen from a pool of introductory Psychology students at Carleton University. All participants had normal or corrected to normal vision and were native English speakers. They received one course credit for their participation.

Materials and Design

The experimental stimuli were all monosyllabic and chosen from a pool of low-frequency regular (LFreg) (see Appendix A) and low-frequency irregular (LFirr) (see Appendix B) words for which polysemy could be determined. All words within each of the word-type groups had a value of 30 or less according to Kucera and Francis' (1967) word corpus, which represents the frequency of printed occurrence in the language. In light of Gernsbacher's caution regarding a possible confound of word familiarity with frequency

and/or polysemy, familiarity ratings for the words were obtained. As all words are low-frequency, confounding familiarity with frequency was not a concern. However, pilot and experimental participants were required to rate all words according to familiarity to reduce the possible risk of confounding polysemy with familiarity (see Appendix C for individual word ratings).

Low-frequency regular words were selected from the corpus used in Borowsky and Masson (1996) which were closely matched on initial phoneme, number of letters, and frequency. A word was selected as *regular* if its grapheme-to-phoneme conversion was consistent and it belonged to a consistent orthographic neighbourhood (e.g., bank). The orthographic neighbourhood value (N) of a word is the number of different words that can be formed from it by changing one letter at a time (see Coltheart, Davelaar, Jonassen & Besner, 1977). Low-frequency irregular words were classified according to Venezky's (1970) rules which classifies a word as irregular if it does not follow consistent grapheme-to-phoneme rules (e.g., palm).

The words were further separated according to number of meanings as specified by Webster's Standard American Dictionary. A word was deemed nonpolysemous if it had only one meaning and polysemous if it had more than two familiar meanings. Although many words exist that are irregular and of low-frequency, it was also the case that their meanings were obscure. This placed a severe limitation on the number of available words to satisfy Gernsbacher's (1984) concerns regarding a possible confound with familiarity.

Within each of the two word type groups (LFreg and LFirr) each polysemous word was paired with a nonpolysemous word according to the matching criteria discussed

above. This procedure resulted in 60 pairs. Thus, 30 pairs constituted a matched subset within the full stimulus set of 120 words. In addition, 12 regular words of medium frequency (Kucera & Francis range of 30-70 per million) were selected as practice items. Words within the regular/irregular subsets were matched on initial phoneme, frequency, N and as closely as possible on bigram frequency. Familiar subvocal phonetic patterns (such as bigram frequency) and N can affect naming latencies (Coltheart, Davelaar, Jonasson, & Besner, 1977; Strain, Patterson, & Seidenberg, 1995), and as such are good measures for assessing phonetic familiarity. Based on these criteria, items were matched on both BF and N. The polysemous-nonpolysemous word pairs were also closely matched on overall frequency, N, and bigram frequency. To ensure equivalent measures for the word characteristics ANOVAS were conducted on the critical factors (frequency, N, and bigram frequency). There were no significant differences. The statistical characteristics for polysemy (one versus many) are presented in Table 1 and for each word group in Table 2 (See Appendix A for individual regular words and Appendix B for individual irregular words).

Table 1
Statistical Characteristics for Polysemy Groups

Word Group	Frequency	N	Bigram Frequency
Nonpoly	10.0	6.7	3855
Poly	10.1	8.3	5034

Table 2
Statistical Characteristics for Word Groups

Word Group	Frequency	N	Bigram Frequency
<u>Regular</u>			
Nonpoly	12.1	8.7	3356
Poly	12.0	10.7	4690
<u>Irregular</u>			
Nonpoly	8.0	4.5	4355
Poly	8.1	5.8	5379

Familiarity rating task. Participants were required to rate the experimental stimuli on a 7-point familiarity scale, using 1 (low familiarity) to 7 (high-familiarity) inclusively (see Appendix C). In addition to the experimental participants, an independent sample was drawn from the first year Psychology pool to complete these ratings in a pilot study. Due to potential carry-over effects from the experimental trials, this design was deemed best for obtaining pure measures of stimulus familiarity.

Polysemy metric. As an added control along this dimension, meanings were participant-generated to complement the initial method for the polysemous/nonpolysemous classification. Participants in the pilot study and participants in the experiment proper indicated the number of meanings for each of the experimental stimuli. The 60 polysemous and 60 nonpolysemous words were randomly ordered and listed in a questionnaire format. Participants were required to indicate the number of meanings for each word by circling

(1) one meaning or (2) more than one meaning. In this way, an *accessible polysemy* measure was obtained to provide a better metric for comparison within the stimulus set to validate the initial classification of this variable (see Appendix C). According to Millis and Button (1989), accessible polysemy represents the number of meanings that participants can actually access. Coupled with number of dictionary definitions this additional index should provide an accurate index of polysemy.

Data from the two rating scales were analyzed to ensure that the word groups had been properly selected. The cutoffs for ensuring polysemy was a mean greater than 1.5 for polysemous words and less than 1.4 for nonpolysemous words. Overall means from the pilot and experimental sessions were calculated in separate analyses and produced similar results: a mean of 1.6 for polysemous words and 1.1 for nonpolysemous words, $F(1, 116) = 105.98$, $p < .001$. In contrast, the two familiarity ratings produced similar results. Collapsing across the four word groups resulted in no differences on the familiarity dimension: regular nonpolysemous (2.4), regular polysemous (2.4), irregular nonpolysemous (2.9) and irregular polysemous (2.8).

Apparatus

An IBM-type 80386 computer equipped with a Soundblaster audio card was used to present letter strings on a Samsung monochrome video monitor and to record naming responses. Participants were seated approximately 50 cm from the video monitor.

Procedure

Participants were tested individually. Each participant was tested in an online condition followed by a delayed condition. Items were presented in one order for the online naming

task and in the reversed order for the delayed naming task. The order of word lists was counterbalanced across participants. In the online condition each participant was instructed to pronounce a letter string as quickly and as accurately as possible. Instructions were followed by a block of 12 practice trials and then 120 experimental trials. Items were presented in two random orders with the constraint that each half of the list was composed of one-half regular and irregular polysemous, and one-half regular and irregular nonpolysemous words. At the beginning of each trial participants saw an asterisk which served as the fixation point. Participants pushed the center button on a three-button response panel to begin each trial. An interval of 500 ms followed the button press, after which the letter string appeared and remained on the screen until a response was given. Responses were coded on-line by the experimenter according to correct, incorrect, or invalid.

In the delayed naming condition letter strings were presented for 500 ms, followed by a centrally presented asterisk. Fifteen hundred milliseconds later two sets of arrows appeared horizontally surrounding the asterisk where the word previously appeared (<< * >>). This cue served as the participants' signal-to-respond. Participants were required to execute the naming response as quickly and as accurately as possible. Latencies were recorded from the onset of the arrow cue to the triggering of the voice activated relay mechanism.

Results

Latencies greater than 5000 ms were considered invalid and excluded from the analysis. In addition a trial was considered invalid if a naming response failed to activate

the voice mechanism, or if the mechanism was activated by extraneous noise. This resulted in 58 (1.5%) of the total 3840 experimental trials in the online condition being excluded from the analysis. Overall error rates in this condition involved 6% of the total 3840 experimental trials. Median naming latencies for 3552 correct responses (92.5% of the total experimental trials) and mean error rates were calculated separately across subjects and items. In the delayed condition, latencies greater than 5000 ms were considered invalid. In addition, a trial was considered invalid if a response was triggered before the cue to respond appeared. This resulted in 42 (3.7%) of the total 3840 experimental trials being eliminated from the overall analysis. Of the remaining trials, 111 (2.9%) resulted in errors. Median response latencies for 3587 (93.4%) correct trials and mean error rates were calculated separately across subjects and items.

Latencies. The median naming latencies averaged across the four word groups are shown in Table 3. Median response latencies for each of the 120 items used in the experimental trials are presented in Appendix D (see Tables D1 and D2). Measures of variability obtained in the online and delayed naming conditions are presented in Appendix E.

Any confounding effects due to speech production were removed by subtracting the delayed naming latencies from the online naming latencies. All analyses were conducted on these corrected (difference scores) latencies. In the participant analysis a two-factor within-subjects ANOVA design with two levels of regularity (regular, irregular), and two levels of polysemy (one meaning, many meanings) was conducted. In the items analysis these two factors were used in a mixed ANOVA design using regularity as the between-

items factor and polysemy as the within-items factor. Analyses revealed a significant main effect of regularity for both participants, $F_1(1,31) = 77.51$, $MSe = 1440.97$, $p < .001$ and items, $F_2(1, 58) = 22.70$, $MSe = 3234.81$, $p < .001$. Participants named regular words (101 ms) faster than irregular words (160 ms). In addition participants were faster to name polysemous words (122 ms) than nonpolysemous words (138 ms), $F_1(1,31) = 6.76$, $MSe = 1218.55$, $p < .01$. The polysemy effect was not significant for items, $F_2(1,58) = .39$, $MSe = 1374.67$, $p = .533$. Furthermore, a significant interaction between the regularity and polysemy variables was significant by participants, such that naming latencies to irregular words were modulated by polysemy, $F_1(1,31) = 5.06$, $MSe = 1124.35$, $p < .03$, however, this interaction was not significant by items $F_2(1, 58) = 2.56$, $MSe = 1374.67$, $p = .115$.

Table 3

Mean Median Latencies and Percent Errors for Online and Delayed Naming

Word Type	<u>Online Naming</u>		<u>Delayed Naming</u>		<u>Difference Scores</u>			
	RT	% Error	RT	% Error	RT	SD	% Error	SD
<u>Regular</u>								
Nonpoly	550	2.0	448	0.2	102	115	1.7	2.5
Poly	548	1.0	449	0.4	99	106	0.6	2.2
<u>Irregular</u>								
Nonpoly	626	11.0	452	6.7	174	121	4.5	5.7
Poly	602	10.0	457	4.7	145	110	5.7	4.9

As shown in Table 3, naming responses were faster to an irregular word having more

than one meaning (145 ms) relative to an irregular word having only one meaning (174 ms). However, latencies to regular words were equally fast whether the word had one meaning (102 ms) or more than one meaning (99 ms). Simple comparison analysis conducted on the irregular word medians confirmed that the 30 ms difference observed between the polysemous and nonpolysemous items was reliable for participants, $F_1(1,31) = 7.81$, $MSe = 1768.22$, $p < .01$ but not for items $F_2(1,31) = 1.75$, $MSe = 1940.89$, $p = .196$.

Errors. The distribution of errors over the four word types is presented in Table 3¹. Error rates for each word are presented in Appendix D (see Tables D1 and D2). As in the latency data, the error analysis was conducted on the corrected scores obtained by subtracting the delayed error rates from the online error rates. In the subject analysis a two-way within subjects ANOVA design was conducted using regularity (regular, irregular) and polysemy (one meaning, many meanings) as the repeated factors. In the items analysis these two factors were used in a mixed ANOVA design using regularity as the between-subjects factor and polysemy as the within-subjects factor. A main effect of regularity was obtained both in the subject analysis, $F_1(1,31) = 24.82$, $MSe = 20.11$, $p < .001$, and in the items analysis, $F_2(1, 58) = 14.28$, $MSe = 34.77$, $p < .001$, indicating that responses were more accurate to regular words (1.1% errors) than to irregular words (5.1% errors). No other effects reached significance.

In summary, the results are in accord with the hypothesis initially proposed: response times were faster to polysemous, irregular words than to nonpolysemous, irregular words. This finding suggests that the role of meaning in online naming becomes most evident for

words having an irregular spelling-to-sound correspondence. As hypothesized, semantics was expected to manifest an effect only for irregular words, a notion clearly supported in the latency data.

Discussion

The present research was directed toward developing a functional role of semantics in phonological coding. It was predicted that multiple semantic representations would facilitate word naming. Finding an overall effect of polysemy supports this view. The significant interaction between polysemy and regularity extends this view by showing that irregular words benefit more from having many meanings than do regular words. Finding a significant interaction after production effects are removed further supports the claim that semantics benefits the O-P conversion process during lexical access, not during speech production. That phonological representations are more readily accessible for these same words is supported by the latency data. These data are problematic for distributed models such as the one suggested by Borowsky and Masson (1996) because polysemy should not show a processing advantage in the naming task.

Borowsky and Masson found a polysemy effect in lexical decision when orthographically legal nonwords were used. No longer able to make a word/nonword decision based on familiar orthographic patterns, participants needed to process words more deeply to distinguish them from nonwords. However, when illegal nonwords were used, the effect diminished, thus implying a semantic locus for the polysemy effect. This refutes the model proposed by Kawamoto, Farrar, and Kello (1994) which predicts that the polysemy effect is a product of stronger connections between orthographic units. If the

locus of the polysemy effect is at the orthographic level, the inclusion of illegal nonwords into the stimulus set should not diminish its effect. While Borowsky and Masson were able to replicate a polysemy advantage in a lexical decision task, they were unable to obtain significant effects in the naming task.

Borowsky and Masson simulated the naming task by training their implemented model on two polysemous and two nonpolysemous words. Because the polysemous words each had a distinct meaning, the two word types were experienced equally as often. Therefore, any observed differences in the model's performance could not be attributed to differences in frequency of exposure. The number of processing cycles the model required to reach a stable state was used as the measure of response time and equated to a subject's response. No effect of polysemy was observed in the naming task using these simulations. Yet using the same simulations they were able to replicate human performance in the lexical decision task.

To explain their results from the naming task, Borowsky and Masson assume differential activation rates for the meanings of polysemous and nonpolysemous words. One meaning of a polysemous word is more strongly activated than is the only meaning of a nonpolysemous word simply due to random factors. This is also the view described as the proximity effect by Joordens and Besner (1994). A meaning unit is activated for a word having multiple meanings because the starting pattern is more likely to be closer to one of its two meanings than it is to the only meaning for a nonpolysemous word (at this point the polysemy advantage in lexical decision emerges). Later, the situation reverses and the meaning for a nonpolysemous word becomes more highly activated. The reason

that there is no effect of polysemy in the naming task is due to this stronger connection between the meaning and phonological units for the nonpolysemous word. Borowsky and Masson validate this logic by assuming that the polysemous word has two distinct meanings that are each experienced once, whereas the nonpolysemous word has only one meaning, yet it is experienced twice. If, however, this were the case, one should expect a polysemy disadvantage in the naming task because nonpolysemous words would be activated earlier than polysemous words. While Borowsky and Masson do acknowledge this possibility, their account is still in disaccord with the polysemy advantage obtained in the present research.

It should also be noted that although each meaning of a polysemous word is only experienced once during Borowsky and Masson's training regimen, all meanings still map onto the same phonology. As such, phonological output remains consistent for polysemous words. It is difficult to imagine why this would result in weaker semantic to phonological connections for the polysemous word, and, particularly, why the random factors logic would not also apply in the naming task. Because the starting pattern to activate a meaning unit is closer for a polysemous word than it is for a nonpolysemous word, a polysemy advantage in naming should also result. Clearly, the data from the present research provide a challenge to the Borowsky and Masson account.

Models Assuming Competing Representations

Connectionist models have a general difficulty accounting for the polysemy effect because a distributed representation computed from orthographic and phonological connection weights would have to settle on two competing semantic representations. If

competing representations are accessed across a semantic processing unit, the polysemy effect should reflect an increase in response latencies for words with multiple meanings rather than the reverse. It is precisely this one-to-many mapping that poses the connectionist problem. Thus, by implementing the proximity effect, this problem is eliminated. What is not eliminated, however, is the problem of accounting for polysemy effects obtained in naming.

Localist models, on the other hand, such as Morton's (1969) logogen model, McClelland and Rumelhart's (1981) interactive-activation model, and Becker's (1980) verification model assume that a collective threshold is derived from the cumulative sum of activation across all possible "logogens". Each word has one detector for orthographic input, but has multiple detectors for each concept of the word. When activation in a detector reaches threshold, a word is recognized. One possibility for the polysemy advantage is the greater probability of a polysemous word activating one of its multiple meanings before a nonpolysemous word can activate its only meaning. Another possibility is that activation levels are summed across logogens such that a polysemous word results in a higher average of semantic activation than a nonpolysemous word. According to localist and multiple-route models, having multiple semantic representations should benefit word recognition by providing more information about a word. Hence, a word having multiple meanings should reach threshold sooner than a word having one meaning. For connectionist models lacking a contextual layer these multiple representations are a source of processing conflict. Consequently, performance based on the conversion from print to sound is impaired.

Explanations of the polysemy effect have favoured multiple, semantic entries that are activated separately (e.g., Forster & Bednall, 1976; Jastrzembski, 1981), but this does not preclude the notion that activation could be summed across entries at a conceptual level. The PDP solution to account for the effects of polysemy is to posit a semantic module that mimics the impact of semantic representations. Plaut, McClelland, Seidenberg, and Patterson (1995) have recently incorporated such a processing pathway (to complement the phonological pathway) that transforms orthographic representations into semantic representations. A second function of this pathway is to transform semantic representations into phonological representations. Because Plaut et al. have implemented this second pathway to explain naming irregular words, the model resembles a typical dual-route, and the model loses the connectionist notion of a single-route for word processing. Also lacking is a precise account of how semantics operates. The following account is one that is plausible.

Polysemous words share the same orthographic and phonological pattern, yet their meanings differ. Because multiple meanings are activated in the semantic module, this module becomes highly active. Because polysemous words have multiple meanings, they benefit more from semantic activation more than do nonpolysemous words: hence, the polysemy advantage. Furthermore, phonological output does not demand that a specific meaning has to be activated, so the impact of semantics could be that the activation for all possible entries is summed. Thus, semantics may become a more heavily weighted variable and serves to reduce the number of processing cycles necessary to settle on a response. In this way, the polysemy effect is explained. The approach offered below is centered around

this account and is similar to the one offered by Strain, Patterson, and Seidenberg (1995).

Proposed Account for Polysemy Effects in Naming

Readers may learn very early how to access the phonology for high-frequency words. Because these words are frequently experienced, phonology may be derived directly from the orthographic structure. Meaning may also be derived directly from orthography, and offers another way to access phonology. Reading to pronounce, however, differs from reading to understand in that the latter relies on the use of semantics. In the standard naming task participants are required to pronounce letter strings. Because the connections for high-frequency words are well established, deriving phonology directly from orthography is efficient and accurate. Thus, response latencies and error rates are minimal. Semantics may play a role, but accessing meaning does nothing to facilitate pronunciation.

On the other hand, deriving phonology for low-frequency words may take longer than for high-frequency words simply because processing units are not as strongly connected. Weaker connections between processing units means an increase in the number of processing cycles necessary to produce a phonological response. Increased latencies to low-frequency words are precisely what we observe in the data. Temporal delays in processing may allow the semantic unit to become more highly activated to the extent that processing begins to be influenced by its impact. Thus, the naming latencies on low-frequency words show more benefit from semantics than do high-frequency words. Introduce another variable known to influence phonology, such as regularity, and the semantic influence becomes even more marked. Because deriving phonology for low-frequency, irregular words is neither efficient or accurate based solely on orthography, it is

plausible to assume that phonology is derived from the meaning unit. The significant polysemy by regularity interaction reported in the present research supports this view.

This model also offers a possible explanation for deriving a word's specific meaning. When processing demands are such that particular meanings must be accessed (e.g., John went to the bank by the river), a contextual unit may also contribute weight, as directed by the task demands. One possibility is that all representations are activated at the same time but the meaning that best fits the context becomes more highly activated in the process. Such a model would predict a polysemy disadvantage in reading, which is the common finding (see Simpson, 1984).

Relevant to the present study, however, is the notion of an increase in weight for the semantic processing unit. Particularly important is the fact that words are presented in isolation so that any "inhibiting" effects of context on the activation of specific meanings are absent. Any influence of multiple meanings should be most evident in this condition. An emphasis on semantics may also reduce the number of processing cycles needed to pronounce low-frequency, irregular words. The added impact of a semantic unit on phonological settling and patterns of orthographic-to-phonological connections results in similar predictions as were made in the present research. Specifically, that a more heavily weighted semantic variable will achieve the processing resolution necessary for a faster phonological response. Hence, the present research rests on the assumption that an input mechanism to resolve conflict may be provided by the semantic code. Semantics may aid phonological coding by offering an additional processing resource. When factors that are critical to the phonological process are no longer reliable, meaning comes into play. In this

way pronunciation is more readily determined.

Multiple Representations

It could be argued that multiple representations are redundant. Polysemous words have two or more meanings, each with a corresponding lexical entry. On this view a word such as *register* could be represented in the lexicon at least eight times for a highly literate person. In accord, parsimony does appear to be violated. In other words, multiple representations of the same word seems to violate cognitive economy. However, such a view assumes that lexical representation and semantic representation are synonymous. Logic of this form presupposes that lexical access is semantic access, and one loses the perceptual-semantic distinction. Alternatively, one could argue that number of meanings has nothing to do with the lexicon. That is, the polysemy effect simply reflects the notion that each meaning has a separate lexical entry. If, however, we assume that meaning and the lexicon are independent, then we fail to construct a lexicon that is composed of meaning (see Balota, Ferraro, & Connor, 1991 for a review of these issues).

If lexical representations and semantic representations are distinct, then the problem of having separate lexical entries for each meaning of a word is eliminated. If it is assumed that a lexical entry is characterized by a word's orthographic form, then each word would have one lexical entry. If it also assumed that a semantic entry is characterized by the number of meanings a word has, then polysemy is a distinct variable in a lexicon that is composed of both orthographic and semantic features. This does not preclude the view that polysemy affects the lexical access process because both semantics and lexicality are lexical components. When this notion of competing semantic representations is discarded

in favour of an overall threshold of semantic activation, summed across all activated entries, the semantic unit can become extremely influential in processing.

Explaining the semantic unit as the summed activation across all meanings also allows for individual processing differences. Differences in performance are readily linked to differences in lexical fluency. The more semantic representations that are activated, the more heavily weighted the semantic unit becomes. In fact, Plaut and Shallice (1993) found that their simulated network failed to settle on one meaning for a word having two meanings. Rather than producing a pattern specific to one meaning, the network produced patterns that were combinations of both meanings. This pattern was also observed by Joordens and Besner (1994), and by Masson (1991). Such combinations of learned patterns have been termed *blends* and tend to be problematic for models that assume settling on one semantic pattern.

Given that isolated word recognition does not involve accessing any one concept, the notion of blends seems indicative of human performance, at least at an intuitive level. If the semantic unit is to be heavily weighted, then it makes sense that all possible concepts would be activated, particularly when the response does not require accessing one specific concept. In fact, because the phonology for a polysemous word remains consistent for all meanings, activating all meanings could facilitate a naming response. I do, however, believe that a distinction between activated meaning and accessed meaning is in order.

As previously suggested, activating and accessing a particular concept are really two different processes and result from specific task demands. For example, activation of all possible meanings is quite plausible when words are presented in isolation, as in naming.

This is because no one meaning has to be accessed to execute a naming response.

Accessing a specific meaning becomes necessary when words are presented in text, as in reading. Input from a contextual layer to inhibit competing responses would then involve the problem of settling on one meaning for a word. Blends may reflect the partial activation for each meaning of a polysemous word, yet all meanings map onto one phonology. Therefore, the "blend problem" as it relates to single word naming should not be viewed as detrimental.

Dual-route Account

Dual-route models can also account for the data obtained in the present study. Given the differential timecourse for processing along the lexical and nonlexical routes, a temporal account of semantics is again plausible (c.f. Humphreys & Evett, 1985). Because processing a low-frequency irregular word takes time, semantics has enough time to resolve any phonological conflict that results from two competing responses. However, lacking a semantic processing route poses some theoretical problems for the dual-route model. Semantics could be incorporated into the lexicon if we accept the fact that a lexicon is composed of meaning. The following account is therefore plausible.

Low-frequency words are processed along both lexical and nonlexical routes which converge into an output buffer for a phonological response. When the word is irregular, two competing responses are offered: one according to the correct whole-word phonology, and the other according to grapheme-to-phoneme conversion rules.

The polysemy advantage obtained in naming can be explained by assuming that multiple semantic representations activate a whole-word phonology in the phonological

lexicon. Regardless of the number of meanings accessed, the phonology remains the same, thus the phonological lexicon activates one correct response. Due to the fact that the number of meanings is greater for a polysemous word than a nonpolysemous word, the phonological lexicon produces a response faster for polysemous words. This is because the chances are greater that a whole-word phonology will be accessed sooner for one of the many meanings compared to the only one for the nonpolysemous word. Low-frequency, irregular words are the group that should show the most significant effects of this processing advantage. Indeed, the present findings of an overall polysemy effect, and particularly that low-frequency, irregular words with multiple meanings are advantaged over those having only one meaning, support this account.

Summary

The data from the present research indicate faster latencies to words having multiple meanings compared to words having one meaning. These data also indicate that these effects are maximized for the irregular word group. The finding of a polysemy effect, and, particularly, the interaction between regularity and polysemy found in the present research, cannot be addressed using Borowsky and Masson's (1996) account. They assume that activation occurs at the same rate for polysemous and nonpolysemous words when a naming response is required. As such, one has difficulty when using their model to explain the present findings. It is proposed that Borowsky and Masson (1996) failed to find polysemy effects in naming because they failed to manipulate the factors that would direct processing toward semantics: frequency and regularity. When Borowsky and Masson manipulated orthography, one of the factors critical to lexical decision, they reported a

significant polysemy effect. Had they also manipulated phonological factors critical to naming, perhaps the effect would have reached significance.

Based on the present research, semantic input appears to resolve phonological inconsistency. Further research is required to establish this finding and to explore semantic functions in phonological coding .

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Appendix A
Characteristics for Regular Word Pairs

Poly	Freq	BF	N	Nonpoly	Freq	BF	N
ace	15	358	9	ate	16	37	8
bat	18	767	23	bet	20	2446	1
bluff	8	1148	2	bloat	8	3045	3
bolt	10	3729	14	bite	10	9118	14
boot	13	5935	20	buzz	13	400	1
buck	20	4364	14	bold	21	4364	14
dash	11	3741	10	duke	11	3325	18
deck	23	2584	8	disk	25	1408	8
drag	15	615	6	dish	16	1514	6
duck	9	4338	15	dusk	9	2664	11
foil	20	1870	1	fame	18	9639	14
hail	10	9022	13	hunt	10	2068	9
hog	3	1096	2	hug	3	115	13
hound	7	12056	7	hitch	5	5303	7
jerk	2	6786	1	jolt	4	2466	7
lean	20	7290	14	loud	20	3687	4
loaf	4	2722	4	lint	4	6448	10
mint	7	4542	11	maze	6	4003	12
pet	22	2648	22	pig	23	541	16
punch	5	5944	5	plumb	5	1437	3
ram	2	352	17	rum	3	321	12
sack	8	8052	14	sane	8	7522	20
seal	17	587	13	soup	16	4019	6

Poly	Freq	BF	N	Nonpoly	Freq	BF	N
shed	11	11262	4	shoe	14	1340	5
sink	23	3441	11	soap	22	3141	6
stall	18	8431	7	steam	17	6517	4
steer	9	12759	4	stack	9	8181	10
tag	5	326	19	tee	5	1078	12
tick	3	4003	13	turf	3	1152	3
tire	22	9920	12	tent	20	3250	16

Appendix B

Characteristics for Irregular Word Pairs

Poly	Freq	BF	N	Nonpoly	Freq	BF	N
bull	14	6252	15	bush	14	2796	12
bind	4	4651	12	bald	5	4610	9
calf	11	3979	4	climb	12	1590	1
comb	6	4581	7	caste	3	4445	6
chord	7	5032	2	choir	9	6250	5
chute	2	3793	0	shove	2	5978	3
dough	13	8545	5	dose	11	5329	11
dour	2	5270	7	dearth	2	5332	11
gauge	12	1839	1	ghost	11	6340	0
guild	7	9114	3	guise	6	6146	2
grind	2	8143	2	glove	9	3311	3
hood	7	6105	9	hind	7	5096	8
hook	5	6122	11	hearth	4	4648	4
mould	1	1919	3	mauve	1	2627	0
pour	9	3793	10	pork	10	6944	9
quartz	1	1559	1	qualms	1	826	0
storm	26	5558	2	suite	27	4409	3
swamp	5	927	2	sworn	5	1284	3
stead	5	6696	4	stealth	5	4024	1
sponge	7	2667	1	scarce	6	3671	0
squash	2	957	1	soot	1	6502	15

Poly	Freq	BF	N	Nonpoly	Freq	BF	N
seize	6	1891	3	sew	6	3700	16
swear	10	3025	4	squat	7	1108	1
tread	5	5579	5	troupe	3	5556	1
trough	3	6920	2	thwart	3	4152	0
toll	16	8202	11	ton	13	1444	19
worm	4	6784	9	womb	1	4243	3
ward	25	4198	18	warmth	28	4436	0
worn	23	6554	12	wealth	22	3616	0
warp	4	3456	9	wharf	4	9870	0

Appendix C

Means for Familiarity and Meaning Ratings: Regular Words

Poly Word	Fam Rating	# Meanings	Nonpoly Word	Fam Rating	# Meanings
ace	2.0	1.9	ate	1.1	1.0
bat	1.7	1.9	bet	1.6	1.1
bluff	2.7	1.4	bloat	3.2	1.1
bolt	2.4	1.8	bite	1.4	1.2
boot	1.3	1.6	buzz	2.3	1.4
buck	2.5	1.8	bold	1.8	1.0
dash	2.4	1.6	duke	2.7	1.0
deck	1.7	1.9	disk	1.4	1.3
drag	1.8	1.9	dish	1.3	1.4
duck	1.8	1.8	dusk	2.3	1.1
foil	2.6	1.8	fame	2.0	1.0
hail	2.3	1.8	hunt	1.8	1.0
hog	2.0	1.7	hug	1.2	1.0
hound	2.4	1.8	hitch	2.5	1.3
jerk	1.7	1.8	jolt	2.6	1.3
lean	1.7	1.7	loud	1.2	1.1
loaf	1.9	1.6	lint	1.9	1.0
mint	1.9	1.7	maze	2.5	1.0
pet	1.2	1.7	pig	1.4	1.4
punch	1.6	1.8	plumb	4.1	1.1
ram	2.8	1.8	rum	1.6	1.0
sack	1.9	1.6	sane	1.9	1.1

seal	2.3	1.8	soup	1.5	1.0
shed	2.0	1.9	shoe	1.5	1.1
sink	1.4	1.8	soap	1.2	1.1
stall	2.4	1.9	steam	1.9	1.3
steer	2.7	1.7	stack	2.0	1.4
tag	1.9	1.6	tee	3.0	1.2
tick	2.4	1.8	turf	2.9	1.4
tire	1.7	1.8	tent	1.7	1.1

Means for Familiarity and Meanings Ratings: Irregular Words

Poly Word	Fam Rating	# Meanings	Nonpoly Word	Fam Rating	# Meanings
bull	1.9	1.8	bush	1.7	1.3
bind	2.7	1.4	bald	1.8	1.0
calf	1.8	1.7	climb	1.5	1.0
comb	1.6	1.5	caste	4.9	1.1
chord	2.6	1.7	choir	2.5	1.0
chute	3.4	1.4	shove	2.5	1.0
dough	2.2	1.8	dose	2.3	1.3
dour	5.6	1.0	dearth	6.1	1.0
gauge	3.6	1.6	ghost	1.9	1.0
guild	4.7	1.4	guise	5.0	1.0
grind	2.2	1.4	glove	1.3	1.0
hood	2.0	1.6	hind	3.2	1.1
hook	1.9	1.6	hearth	4.4	1.1
mould	3.5	1.5	mauve	3.7	1.0
pour	1.7	1.4	pork	1.6	1.3
quartz	3.1	1.4	qualms	4.2	1.1
storm	1.5	1.4	suite	2.1	1.0
swamp	2.7	1.6	sworn	2.3	1.2
stead	4.3	1.1	stealth	4.0	1.1
sponge	1.9	1.4	scarce	2.9	1.0
squash	2.4	1.9	soot	4.3	1.0
seize	2.1	1.5	sew	2.5	1.2
swear	1.4	1.4	squat	2.7	1.3
tread	3.0	1.7	troupe	4.9	1.1

trough	3.9	1.4	thwart	5.0	1.0
toll	2.4	1.5	ton	2.0	1.1
worm	2.0	1.6	womb	2.1	1.0
ward	3.5	1.5	warmth	1.4	1.1
worn	1.7	1.4	wealth	1.8	1.0
warp	3.2	1.5	wharf	4.1	1.0

Appendix D

Table D1
Mean Median Online Naming Latency (in ms) and Percent Errors for Items:
Regular Words

Polysemous Word	Median	Errors (%)	Nonpoly Word	Median	Errors (%)
ace	527	0	ate	533	0
bat	524	0	bet	513	3.1
bluff	537	6.3	bloat	522	3.1
bolt	497	0	bite	506	0
boot	537	0	buzz	499	0
buck	526	0	bold	508	3.1
dash	495	0	duke	544	0
deck	502	3.1	disk	491	3.1
drag	527	0	dish	493	0
duck	499	0	dusk	507	0
foil	589	0	fame	579	3.1
hail	553	6.3	hunt	555	0
hog	649	0	hug	551	0
hound	654	0	hitch	534	3.1
jerk	525	0	jolt	560	0

Median Online Naming Latencies and Errors: Regular Words (cont'd)

lean	493	3.1	loud	460	0
loaf	522	0	lint	522	0
mint	473	0	maze	486	0
pet	504	0	pig	495	0
punch	499	0	plumb	534	6.3
ram	517	0	rum	525	3.1
sack	582	0	sane	572	0
seal	590	3.1	soup	577	21.9
shed	614	0	shoe	602	0
sink	578	6.3	soap	562	0
stall	594	0	steam	618	6.3
steer	648	0	stack	591	3.1
tag	552	0	tee	564	0
tick	520	0	turf	552	0
tire	527	0	tent	520	0

Table D2
Median Online Naming Latency (in ms) and Errors (%) for Items: Irregular Words

Polysemous Word	Median	Errors	Nonpoly Word	Median	Errors
bull	521	0	bush	531	6.3
bind	679	37.5	bald	549	0
calf	541	0	climb	557	0
comb	590	0	caste	586	34.4
chord	661	6.3	choir	742	6.3
chute	694	0	shove	600	3.1
dough	586	6.3	dose	535	0
dour	708	18.8	dearth	722	20.7
gauge	621	46.9*	ghost	514	0
guild	656	12.5	guise	668	15.6
grind	554	0	glove	553	0
hood	550	3.1	hind	678	12.5
hook	502	0	hearth	643	3.1
mould	537	0	mauve	553	25.0
pour	550	3.1	pork	522	0

Median Online Naming Latencies and Errors for Irregular Words (cont'd)

quartz	632	3.1	qualms	702	3.1
storm	594	0	suite	682	37.5
swamp	578	0	sworn	620	0
stead	592	50.0*	stealth	659	6.3
sponge	625	0	scarce	661	28.1
squash	587	0	soot	731	68.8*
seize	602	6.3	sew	598	21.9
swear	574	0	squat	662	0
tread	612	6.3	troupe	650	3.1
trough	778	43.8*	thwart	693	6.3
toll	529	3.1	ton	523	15.7
worm	504	34.4	womb	524	3.1
ward	524	3.3	warmth	565	0
worn	515	12.5	wealth	564	3.1
warp	550	9.4	wharf	519	6.3

Note. Items designated by an asterisk (*) produced the same pattern of errors in the online and naming tasks.

Table D3
Median Delayed Naming Latencies (in ms) and errors (%) for Regular Word Pairs

Polysemous Word	Median	Errors (%)	Nonpoly Word	Median	Errors (%)
ace	420	0	ate	440	0
bat	441	0	bet	398	0
bluff	398	0	bloat	351	3.1
bolt	387	0	bite	401	0
boot	391	0	buzz	422	0
buck	374	0	bold	386	0
dash	397	3.1	duke	414	0
deck	421	0	disk	411	0
drag	389	0	dish	398	0
duck	400	0	dusk	402	0
foil	437	0	fame	439	0
hail	380	0	hunt	436	0
hog	455	0	hug	437	0
hound	518	0	hitch	404	0
jerk	381	0	jolt	399	0

Median Delayed Naming Latencies and Errors for Regular Words (cont'd)

lean	372	0	loud	405	0
loaf	383	0	lint	378	0
mint	390	0	maze	386	0
pet	407	0	pig	383	0
punch	378	0	plumb	434	3.1
ram	428	0	rum	391	0
sack	472	0	sane	458	0
seal	430	3.1	soup	447	0
shed	473	0	shoe	501	0
sink	475	0	soap	483	0
stall	465	0	steam	493	0
steer	472	3.1	stack	487	0
tag	461	0	tee	418	0
tick	460	0	turf	399	0
tire	454	0	tent	428	0

Table D4
Median Delayed Naming Latencies (in ms) and Percent Errors for Irregular Word Pairs

Polysemous Word	Median	Errors (%)	Nonpolysemous Word	Median	Errors (%)
bull	382	0	bush	406	0
bind	440	15.6	bald	351	0
calf	436	3.1	climb	451	0
comb	402	3.1	caste	412	28.1
chord	435	0	choir	426	9.4
chute	475	0	shove	451	0
dough	371	3.1	dose	421	0
dour	429	3.1	dearth	442	17.2
gauge	426	15.6	ghost	412	0
guild	414	0	guise	400	6.3
grind	397	0	glove	418	0
hood	425	0	hind	525	9.38
hook	408	0	hearth	441	0
mould	391	0	mauve	345	21.9
pour	410	0	pork	377	0

Median Delayed Naming Latencies and Errors for Irregular Words (cont'd)

quartz	468	0	qualms	447	9.4
storm	459	0	suite	465	9.4
swamp	508	0	sworn	435	3.1
stead	546	50.0	stealth	456	3.1
sponge	484	0	scarce	516	9.4
squash	435	0	soot	548	37.5
seize	461	0	sew	457	12.5
swear	479	0	squat	517	0
tread	443	0	troupe	473	3.1
trough	436	34.4	thwart	432	3.1
toll	436	0	ton	468	0
worm	381	3.1	womb	367	3.1
ward	378	0	warmth	411	0
worn	387	0	wealth	392	0
warp	399	3.1	wharf	382	3.1

Appendix E

Summary of Central Tendency and Variability for Word Groups in the Online and Delayed Naming Conditions

Word Type	<u>Online Naming</u>				<u>Delayed Naming</u>			
	RT	SD	% Error	SD	RT	SD	% Error	SD
<u>Regular</u>								
Nonpoly	550	78	2.0	2.9	448	114	0.2	1.2
Poly	548	76	1.0	1.9	448	111	0.4	1.1
<u>Irregular</u>								
Nonpoly	626	103	11.0	6.7	452	105	6.7	5.0
Poly	602	115	10.0	5.0	457	116	4.7	3.5

Note. RT (Response Times in ms); SD (standard deviation)

Footnote

1. It was expected that the errors resulting from processing irregular words would be a result of regularizing the spelling pattern (i.e., *godge* rather than *gauge*). However, the nature of the errors to the three words in question is visual. Further examination of the data revealed that unusually high errors were made to three irregular, polysemous words: 47% errors were made to *gauge*, 44% to *trough*, and 50% to *stead*. The error data in the delayed condition conform to this same pattern (see Appendix D). For example, participants responded to *gauge* by saying *gauze*, and to *trough* by saying *through*. It appears that participants do not know the target words, and so responded by naming a word that is orthographically similar, yet more familiar to them. This view is confirmed by the scores in the familiarity rating scale which clearly indicates that participants are not familiar with these three particular items.

IMAGE EVALUATION TEST TARGET (QA-3)

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