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Polysemy Effects: Evidence For Dual Access Routes To Word Meanings

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by

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ABSTRACT

The effects of polysemy (number of meanings) and word frequency were examined in lexical decision and naming tasks. Polysemy effects were observed in both tasks In the lexical decision task, polysemy was additive with frequency. Polysemy effects appeared for both high and low frequency words. In the naming task, however, polysemy effects interacted with frequency, with polysemy effects being limited to low frequency words. When degraded stimuli were used in both tasks, the interaction appeared not only in naming but also in lexical decision. When pronounceable nonwords were replaced by pseudohomophones in lexical decision tasks, however, polysemy was once again additive with frequency regardless of stimulus quality. The differential patterns of results can be explained in terms of whether the task required orthographically based or phonologically based responses. Since polysemy effects are assumed to be evidence of semantic access, the differential results seem to reflect two independent access routes to semantic representations. The nature of these access routes is discussed.

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INTRODUCTION

One of the most fundamental issues in visual word recognition is how word meanings are retrieved based on visual inputs. This issue seems to consist of two questions: 1) what sort of processes operate to access word meanings? and 2) what types of information are used to access word meanings? In the early sixties, word meanings were assumed to be stored in dictionary-like representations. This representational structure was termed the "lexicon." The lexicon was also assumed to contain nonsemantic information for each word such as spellings, pronunciations, and syntactic classes. Thus, word recognition researchers interested in meaning retrieval had focused their attention on describing the processes or the types of information used to access the lexicon (see, Coltheart, Davelaar, Jonasson, & Besner, 1977; Brown, 1990).

In summarizing this work, Chumbley and Balota (1984) suggest, in fact, that essentially all major models of word recognition such as Morton's (1969) logogen model, Becker's (1980) verification model, and Forster's (1976) lexical search model assume at least two processes in isolated word recognition. The first is the process of accessing the lexicon and the second is the process of meaning determination. The verification model and the lexical search model assume a sequential matching process between evidence extracted from the visual stimuli and lexical representations, with higher frequency words checked first. The logogen model assumes differential threshold values for the lexical representations depending on word frequency. When the activation of a logogen reaches its threshold, lexical access is accomplished. More importantly, these models assume that semantic information becomes available only after lexical access. Thus, in isolated word recognition, these models suggest that semantic variables should have little effect on the lexical access process.

The lexical access process is generally assumed to be an initial input process which is common to a variety of word recognition tasks (e.g., Balota & Chumbley, 1984; Balota & Chumbley, 1985; Chumbley & Balota, 1984). As suggested by Fodor (1983), external information which is given as physical signals has to be initially mapped to mental representations for cognitive processes to access and further operate on that information In visual word recognition, therefore, it seems necessary and reasonable to assume that the lexical access process is an initial input process in which visual signals are mapped to lexical representations on which postaccess processes can then operate.

The assumption that semantic variables have little effect on lexical access has recently been challenged by Balota, Ferraro, and Connor (1991). Through a review of semantic effects in isolated word recognition, they have rather argued that semantic variables influence the speed of lexical access. They explained the semantic effects on lexical access in terms of the interactive-activation model (McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982). The interactive-activation model assumes that lexical access is accomplished when a word level unit is activated over a threshold. Each unit is assumed to have its own resting activation level depending on word frequency. The word level units are connected to higher, meaning level units via bi-directional links. In this model, the partial activation of word level units is assumed to send activation signals up to meaning level units before a word level unit is activated over the threshold The activation of meaning level units, in turn, sends activation signals back down to word level units. This cascading process facilitates a word level unit being activated over its threshold. In this way, the interactive-activation model can explain the influence of semantic factors on the lexical access process.

Given this alternative characterization of lexical access, it has now become important to determine whether semantic variables do, in fact, influence the speed of lexical access and, if so, how. To examine these issues, however, one must first grapple with the problem of determining whether effects which appear in certain word recognition tasks truly reflect the effects which occur during lexical access.

Most word recognition models were developed primarily on the basis of the results from lexical decision experiments. The lexical decision task had been regarded as the principal task for investigating the lexical access process because this task necessarily requires accessing the lexicon to discriminate words from nonwords (e.g., Coltheart, 1978). Balota and Chumbley (1984), however, raised the question about whether lexical decision latency is a good measure of lexical access. They examined word frequency effects not only in the lexical decision task but also in other tasks which are also assumed to require lexical access such as naming and category verification tasks. Since all tasks are assumed to require lexical access, the size of frequency effects should be identical if the effects occur only during the common lexical access process. In fact, however, frequency effects were larger in the lexical decision task than in the naming or in the category verification tasks, indicating that some portion of the frequency effects in the lexical decision task is due to task-specific components. Thus, Balota and Chumbley (1984) argued that frequency effects in the lexical decision task exaggerate the effects of frequency on lexical access because lexical decision latency consists not only of a lexical access component but also of the postaccess decision making components. They, thus, concluded that naming latency is a better measure of lexical access.

However, Balota and Chumbley's (1984) assumption that the naming task involves a lexical access component is controversial because some researchers (e.g., Coltheart, 1978) have argued that pronunciations may often be retrieved via a nonlexical route, based on spelling-sound correspondence rules. Paap, McDonald, Schvaneveldt, and Noel (1987) argued that smaller frequency effects are obtained in the naming task because pronunciations can be retrieved via a nonlexical route They argued that, for example, the first segment of a word could be pronounced via the nonlexical route before the completion of lexical access and the retrieval of the entire pronunciation. They suggested, therefore, that the results from the naming task underestimate the effects of frequency on lexical access and that lexical decision latency is a better measure of the lexical access process. Other researchers (e.g., Glushko, 1979; Seidenberg & McClelland, 1989), however, have argued against this dual route assumption for accessing phonology. Thus, the issue is far from settled (e.g., Paap & Noel, 1991).

Further, although Balota and Chumbley (1984) argued that naming latency is a better measure of lexical access, Balota and Chumbley (1985) pointed out that naming latency also involves postaccess components. They examined frequency effects in a delayed naming task as well as a standard naming task. In the delayed naming procedure, subjects were asked to wait to pronounce a presented word until a pronunciation cue was given. Their results showed significant word frequency effects not only in a standard naming condition but also in delayed naming conditions (e.g., 1400 ms delay condition) whereas word length effects were significant only in the standard naming condition and in the delayed naming condition with a short delay (150 ms). The results suggested that although word length affects only the lexical access process, word frequency affects postaccess production processes as well as lexical access.

Therefore, the overall pattern of results seems to suggest that neither the results from the lexical decision task nor those from the naming task provide a pure measure of lexical access. Regarding this issue, Andrews (1989) stressed the importance of task comparisons for a particular effect. She argued that "evaluations of the patterns of influence of different variables under different task conditions provide a means of specifying the locus of the effects observed" (p. 805). Thus, to examine whether a particular variable has any effects on lexical access, it seems necessary to examine the effects of the variable using a variety of word recognition tasks.

Based on these arguments, the present studies were designed to examine the effects of a semantic variable, polysemy (number of meanings) on lexical access by evaluating its effects in both naming and lexical decision tasks. Specifically, the primary purpose was to examine whether polysemy affects the speed of lexical access.

Polysemy effects have been observed in many word recognition studies (Rubenstein, Garfield, & Millikan, 1970; Rubenstein, Lewis, & Rubenstein, 1971; Jastrzembski, & Stanners, 1975; Jastrzembski, 1981; Kellas, Ferraro, & Simpson, 1988; Millis, & Button, 1989). In these studies, lexical decision latencies were faster for words with multiple meanings than for words with fewer meanings. Rubenstein, et al. (1970) collected ambiguous and unambiguous word groups and these groups were further divided in terms of word frequency (high, medium, and low) and concreteness. They measured the number of meanings by asking subjects to write down the first meaning that came to mind for each word and then counting the number of different meanings produced across all subjects. They then conducted a lexical decision task using these stimuli. Their results showed a significant main effect of polysemy as well as a significant main effect of word frequency. A significant interaction between polysemy and concreteness was also observed but the interaction between polysemy and frequency was not significant. Thus, Rubenstein and his colleagues (Rubenstein, et al., 1970; Rubenstein, et al., 1971) developed a word recognition model in which word frequency and polysemy affect separate stages of processing. In their model, multiple lexical entries for ambiguous words were hypothesized and meaning retrieval consisted of four processes: 1) a quantization process, at first, segments a visual input into letters, 2) the quantization output marks some subset of lexical entries in order of word frequency, 3) marked entries are compared with the subsequent quantization outputs in random order and 4) one of the marked entries is selected as a response when it meets the accuracy criterion. The effects of word frequency were assumed to occur at the marking process. On the other hand, the effects of polysemy were assumed to occur at the comparison process. Since ambiguous words have multiple lexical entries whereas unambiguous words have a single entry. if the comparison occurs in a random order, there should be more chance for ambiguous words to be processed rapidly than for unambiguous words. Thus, their model assumed that polysemy as well as frequency affect the speed of lexical access.

Forster and Bednall (1976) also examined the effects of polysemy and frequency in the lexical decision task. Although they obtained frequency effects, they failed to replicate the effects of polysemy. The sizes of polysemy effects were 11 ms to 27 ms in the right direction but nonsignificant in an analysis treating both subjects and items as random factors. They referred to Clark's (1973) arguments to explain the failure to replicate the effects of polysemy. Clark argued that, in word recognition research, the experimental data has to be analyzed by treating items as well as subjects as random factors to generalize the results beyond the particular stimulus set used in a particular experiment. He reanalyzed Rubenstein, et al.'s (1970) data by treating subjects and items as random factors and failed to obtain a statistically significant effect of polysemy. Therefore, he suggested that the polysemy effects obtained in Rubenstein et al. may not be real, rather, it may have just been a result of variability specific to particular stimulus items.

Clark's argument, however, was criticized by Wike and Church (1976) and others (Cohen, 1976; Smith, 1976; Keppel, 1976). Although Clark suggested the importance of treating items as a random factor in linguistic research, the selection of items is not random because researchers are usually attempting to control irrelevant variables. Thus, item almost never actually is a random factor. Further, by treating items as a random factor, the statistical tests have markedly reduced power and, as a consequence, there is much more risk of Type II errors. Wike and Church concluded that Clark (1973) "is overconcerned with the costs of nonreplicability and underconcerned with the failure to detect differences when they exist" (p.253). Thus, although it is important to consider whether a certain effect is replicable and can be generalized beyond a particular set of items, it seems unwise to ignore effects that are significant only when subjects are regarded as a random factor.

Jastrzembski and Stanners (1975) and Jastrzembski (1981) argued that the previous failure to obtain statistically significant effects of polysemy may be because of relatively weak manipulations of the number of meanings. To obtain a more powerful manipulation of the number of meanings, they counted the number of meanings (definitions) listed for each word in an unabridged dictionary. The idea behind this manipulation was that even if some definitions listed in the dictionary have no corresponding lexical entries (representations), the number of definitions, on average, should provide a better measure of the number of lexical entries than the measure used by Rubenstein and his colleagues. The difference in number of dictionary definitions between ambiguous and unambiguous word groups was 13.8 in Rubenstein, et al. (1970) and 6.2 in Rubenstein, et al. (1971). Thus, Jastrzembski and Stanners (1975) examined the polysemy effects based on relatively larger differences in the number of dictionary definitions (29.3 in Experiment 1 and 23.4 in Experiment 2). Their results showed that lexical decision latencies were significantly faster for words with many definitions than for words with fewer definitions and this effect was statistically significant in an analysis treating subjects and items as random factors. Further, similar to Rubenstein et al. (1970), Jastrzembski (1981) examined the effects of word frequency and polysemy (again indexed by the number of dictionary definitions). The effects of frequency and polysemy were both significant. In addition, he obtained a significant interaction between polysemy and frequency. The size of the polysemy effect was larger for low frequency words (143 ms) than for high frequency words (79 ms). Thus, he argued that his results were problematic for Rubenstein et al's model in which frequency and polysemy are assumed to influence separate processes.

Jastrzembski (1981) tried tc explain the polysemy effect in terms of Morton's (1979) logogen model. The logogen model explains frequency effects by assuming different levels of threshold for high and low frequency words' logogens. Jastrzembski further assumed that ambiguous words are represented by separate logogens with one logogen for each meaning. Since the probability of accumulating bottom-up evidence would be the same for all logogens, the probability of any one logogen reaching threshold would be higher for words with many logogens than for words with fewer logogens. Thus, ambiguous words can be recognized faster than unambiguous words within the frequency-sensitive mechanism.

Gernsbacher (1984), however, questioned the psychological validity of polysemy measured by the number of dictionary definitions. Her informal survey revealed that even well-educated subjects, on average, could report only 3 definitions for the word *fudge*, 2 for the word *gauge*, and 1 for the word *cadet*, although these words have 15, 30, and 15 dictionary definitions, respectively. Thus, it is unclear whether Jastrzembski's (1981) results of polysemy effects were truly caused by the number of meaning factor. Rather, Gernsbacher argued that Jastrzembski's results might be confounded with the effect of "experiential familiarity" for words. She argued that although Jastrzembski manipulated word frequency using frequency counts for printed text, controlling printed-frequency may not be equivalent to controlling the familiarity for a word in everyday experience. Further, it seems likely that familiarity correlates with polysemy. That is, the more meanings a given word has, the more likely it is to appear in everyday life. In her experiment, the number of dictionary definitions and the experiential familiarity were orthogonally manipulated for words which occur once per million in printed text (Thorndike and Lorge, 1944). The words with many meanings had more than 10 definitions in a dictionary and the words with one meaning had only one definition. The experiential familiarity was measured by asking subjects to rate the familiarity using seven point scales. Her results showed only the main effect of familiarity. Neither the main effect of polysemy nor the interaction between polysemy and familiarity was significant. Thus, the results confirmed her arguments that polysemy was confounded with experiential familiarity.

Although Gernsbacher's argument may make sense for low frequency words, it seems a bit unclear whether the same argument can be applied for polysemy effects for high frequency words. When ambiguous and unambiguous words are high frequency, both word groups seem to consist of words with high familiarity. Assuming a logarithmic function for frequency effects on lexical decision latencies, the difference in familiarity between high frequency word groups seems to have little impact on lexical decision latencies. However, Jastrzembski (1981) as well as Rubenstein, et al. (1970) obtained a difference in lexical decision latencies between high frequency ambiguous and high frequency unambiguous words. Thus, although it seems important to notice that polysemy correlates with experiential familiarity, it seems still hard to argue that polysemy has no effect on lexical decision latencies based on Gernsbacher's data.

Further, given the null effect of polysemy reported by Gernsbacher (1984), Millis and Button (1989) attempted to find a more psychologically valid definition of polysemy. They used three different measures of polysemy and examined whether any of those measures of polysemy predict lexical decision latencies. The polysemy measures were applied to ambiguous and unambiguous word groups in which experiential familiarity was matched. First, identical to Rubenstein, et al. (1970), they asked subjects to write down the first meaning of each word and the total number of meanings which appeared across subjects was taken as a measure of polysemy (first-meaning metric). In the first-meaning metric of polysemy, however, polysemy may be underestimated because subjects tend to write down the dominant word meaning and, perhaps, this metric may not reflect all the meanings which can be accessed. Therefore, they used two other measures of polysemy, asking subjects to write down all the meanings they could think of for each word. In the second measure, they counted the total number of meanings generated across subjects and the total number was taken as a measure of polysemy (total-meaning metric). Finally, the average number of meanings generated over subjects was taken as the third measure of polysemy (average-meaning metric). In their lexical decision experiments, polysemy effects were significant in the analyses treating subjects and items as random factors when the total-meaning metric and the average-meaning metric of polysemy were used. But when the first-meaning metric of polysemy was used, the polysemy effect was significant only in item analysis. Therefore, Millis and Button concluded that polysemy affects lexical decision latencies when a measure of polysemy correctly reflects the number of meanings which subjects can access.

At this point, it seems extremely likely that polysemy has significant effects on lexical decision latencies because the polysemy effects were repeatedly replicated by different researchers using different items. However, it is still unclear whether semantic variables affect lexical access since lexical decision latencies involve postaccess components. Chumbley and Balota (1984) addressed this issue. Using multiple regression techniques, they attempted to partial out the lexical access component from lexical decision latencies to determine whether semantic variables affected lexical access or postaccess processing components. Chumbley and Balota, at first, measured associative task latency for each word used in the lexical decision task. The associative task latency was subjects' response latency to pronounce the first associate which came to mind when subjects were presented with a given word. The associative task latency was used as a predictor variable representing meaning availability in the analyses of lexical decision latencies. The results showed that the associative task latency explained some significant portion of lexical decision latencies even after accounting for the significant influence of other predictor variables such as word frequency. Thus, meaning availability appears to affect the speed of lexical decision making. Further, to partial out the lexical access component from lexical decision latencies, they also measured naming latency for each word and the naming latency was added as a predictor variable in a multiple regression analysis. The results, again, showed a significant effect of associative task latency on lexical decision latencies, indicating meaning availability (indexed by associative task latencies) has an effect on the speed of lexical decision at the postaccess stage. A multiple regression analysis was also conducted for naming latencies. In addition to word frequency and word length, semantic variables such as instance dominance (likelihood of producing an exemplar in response to the category name, e.g., Battig & Montague, 1969), polysemy (measured in terms of the number of dictionary definitions), and the number of different associates were used as predictor variables. Word frequency and word length were significant but none of the semantic variables had significant effects on naming latencies (although the effect of polysemy approached significance). Assuming naming latency is an index of lexical access, the results suggested that meaning availability has only minimal effects on lexical access.

If semantic variables do not affect the speed of lexical access and speed is determined by nonsemantic factors such as word length and frequency, it seems unlikely that semantic context would have any effects on the speed of lexical access. Although a number of priming studies have reported semantic priming effects not only in lexical decision but also in naming tasks, there are some pieces of evidence which suggest only minimal effects of semantic context on the lexical access process.

Meyer and Schvaneveldt (1971) demonstrated that lexical decision latencies for target stimuli are affected by a preceding prime word context. When a target was semantically related to a prime (e.g., NURSE-DOCTOR: DOCTOR as the target, NURSE as the prime), lexical decision latency was shorter than when the prime and the target were unrelated (e.g., BUTTER-DOCTOR). Meyer, Schvaneveldt, and Ruddy (1975) attempted to find the locus of this "semantic priming" effect using the additive factors' method (Sternberg, 1969). They manipulated three variables: the quality of the stimuli (clear vs. degraded), the nature of the response (naming vs. lexical decision), and the semantic context preceding the target word (related vs. unrelated). The important result, in terms of additive factors' logic, was that they found only one interactive effect, involving the stimulus quality and the semantic context. The priming effect was 28 ms larger for degraded targets than for clear targets. Since they assumed that stimulus quality affects the encoding stage of word processing (a component of lexical access), their conclusion was that the semantic priming effect also occurs at the encoding stage of word recognition and, hence, semantic context does affect lexical access.

Fischler (1977), however, raised a question as to whether these effects were truly "semantic" effects. He argued that many of these word pairs were associates and that associative relations between words could arise not only from semantic properties of the words but also from "accidents of contiguity." Thus, semantic priming effects obtained by Meyer and his colleagues could not necessarily be ascribed to semantic relatedness. Rather, there is the possibility that some or all of the priming effects were based on word association. Fischler conducted an experiment using semantically related but associatively unrelated word pairs as well as associatively related word pairs. If the priming effect was based on semantic relatedness, the effect should appear even with semantically related nonassociative word pairs. On the other hand, if the basis of the priming effect was word association, there should be no priming effect for the nonassociative pairs regardless of the semantic relatedness. Stimulus pairs were presented simultaneously to subjects and their task was to make lexical decisions for both stimuli (double lexical decision task). Fischler obtained an 84 ms priming effect for semantically related nonassociative pairs and a 99 ms effect for associative pairs. Therefore, he concluded that the semantic priming effect is truly due to semantic relatedness.

Fischler's (1977) findings were replicated by Seidenberg, Waters, Sanders, and Langer (1984) using identical stimuli in a sequential lexical decision task. They obtained a 32 ms priming effect for semantically related nonassociative word pairs and a 31 ms effect for associative pairs. Further, Lupker (1984) also replicated the semantic priming effect for semantically related nonassociative pairs in lexical decision task. He obtained a 26 ms effect for semantically related nonassociative pairs and a 47 ms effect for associative pairs.

However, Lupker's (1984) findings from his naming tasks were problematic for Fischler's (1977) conclusion. Lupker also examined the effect of nonassociative semantic context on naming latencies in his first three experiments. His results showed 6 or 7 ms priming effects. They were always significant in the subjects' analysis but not in the analysis treating subjects and items as random factors. On the other hand, in his fourth experiment, the effect of associative context on naming latencies was larger (18 ms) and significant in both types of analyses. Since the nonassociative semantic priming effects were not significant in the analysis treating subjects and items as random factors, it seems difficult to generalize the small nonassociative semantic priming effect over all possible semantically related nonassociative word pairs. Thus, he claimed that such small effects on naming latencies are best regarded as null results because there is no guarantee that semantically related nonassociative word pairs really have no associative relationship.

Based on his results, Lupker argued that associative and semantic contexts affect different stages of processing. As in Balota and Chumbley (1984), the lexical decision task can be assumed to consist of the lexical access stage and the postaccess decision making stage. Similarly, the naming task is assumed to consist of the lexical access stage and the postaccess pronunciation-related stage. Since associative priming effects were observed in both tasks, the effect seems to occur at the stage which is shared by both tasks. Thus, associative context may affect the lexical access process. Lupker suggested that associative context activates connected lexical entries and facilitates lexical access of the target word. On the other hand, the nonassociative semantic priming effect was task dependent and observed only in lexical decision, so that the effect seems to occur at the stage specific to lexical decision. That is, semantic context may only affect the postaccess decision making stage. Specifically, Lupker suggested that semantic context might facilitate the retrieval of information relevant to decision making. This process may also be active for associative context. That is, the effect of associative context may appear during lexical access and the effect may be augmented at the postaccess stage. Thus, the size of the associative priming effect can be larger in lexical decision than in naming, as was observed.

Balota and Lorch (1986) provided data which support Lupker's view. They examined whether "mediated" associates cause priming effects in naming and in lexical decision. Mediated associates were constructed from two associative pairs. For example, *white* and *coal* were paired because *white* was associatively related to *black* and, further, *black* was associatively related to *coal*. Using such mediated associates, they found a priming effect in naming but the effect didn't appear in lexical decision. The results can be interpreted in terms of the view postulated by Lupker (1984) that associative relations affect the lexical access process, whereas semantic relatedness only affects the retrieval of relevant information at the postaccess decision making processes. Since word association affects lexical access by activating associative lexical entries, the mediated priming effect should be observed in naming tasks. On the other hand, lexical decision also involves the information retrieval/decision making processes. Balota and Lorch argued that subjects might develop a postaccess consistency checking strategy to make word-nonword decisions if the relatedness between the primes and targets appropriately indicates the direction of response. That is, if related targets were highly correlated with "word" responses, subjects might develop a strategy of evaluating the relationship between prime and target when making lexical decisions. Obviously, the relationship between mediated associates such as *white* and *coal* is semantically inconsistent. Therefore, even if lexical access was facilitated by mediated associations, such facilitation would be wiped out at the postaccess decision stage because there is no apparent relationship between prime and target in mediated associates.

McNamara and Altarriba (1988) examined whether the postaccess checking strategy in lexical decision could be suppressed if the relatedness between the prime and target did not reliably indicate the direction of responses. They argued that Balota and Lorch's (1986) subjects developed the checking strategy because a set of directly associated word pairs was used in addition to the mediated associative word pairs and unrelated pairs. If the directly associated pairs were removed, a relation between prime and target would not provide any relevant information for decision making, so that there would be no reason for subjects to develop the checking strategy. Since the mediated priming effects were assumed to occur during lexical access, the effect should appear even in lexical decision tasks if the directly associated word pairs were not included in the stimulus set. Thus, they examined the mediated priming effect in lexical decision with and without directly associated word pairs. When the stimuli contained the directly associated word pairs, as in Balota and Lorch's study (1986), mediated priming effects were not observed. But without the directly associated pairs, a 21 ms mediated priming effect emerged. This indicates that lexical decision latencies are influenced by the postaccess checking strategy and that the mediated priming effect occurs during lexical access.

The results from priming experiments seem to suggest that nonassociative semantic context only affects the postaccess decision making stage, whereas associative context affects the lexical access process. Since the association effects in naming tasks may have been due to the "accidents of contiguity," the association effects do not necessarily imply "semantic" effects on lexical access. On the other hand, the effects of nonassociative semantic context were only minimal in naming tasks. Therefore, similar to the results from Chumbley and Balota (1984), the results from the priming experiments suggest that "pure" semantic context has no effect on the speed of lexical access. Rather, the effect may occur only after lexical access has been accomplished.

Thus, the results from isolated word recognition studies as well as the results from priming studies do seem to converge on the view that the effects of semantic variables have only minimal effects, if any, on lexical access. Rather, these variables influence postaccess processes. However, there are also some data which contradict this view.

Like Lupker (1984), Seidenberg, et al. (1984) examined the effects of nonassociative semantic and associative context on naming latencies using Fischler's (1977) stimuli. The priming effects they obtained were 11 ms for semantically related nonassociative pairs and 9 ms for associative pairs. These effects were small but significant in the subject analysis. Together with the results from lexical decision task (a 32 ms priming effect for semantically related nonassociative pairs and a 31 ms effect for associative pairs), their results suggested that the semantic priming effect was due to semantic relatedness and that semantic relatedness affected the speed of lexical access.

Further, Chumbley and Balota's (1984) polysemy effects (using the number of dictionary definitions) also seem to indicate some possibility of semantic effects on lexical access although the global pattern of results indicated that semantic effects occur only at the postaccess stage. They examined the effects of polysemy in addition to the effects of some other predictor variables on associative task, lexical decision task, and naming task latencies. Polysemy had a significant effect on lexical decision latencies but not on associative task latencies. On naming latencies, the polysemy effect was not significant but approached significance. If the polysemy effect were a postaccess effect, there should still be a significant effect of polysemy on lexical decision latencies even when the lexical access component was partialled out using naming latency as a predictor variable. This should be true regardless of whether associative task latency was included as a predictor variable because polysemy had no effect on associative task latencies. But in the multiple regression analysis for lexical decision latencies including naming latency and associative task latency as predictor variables, the polysemy effect was not significant. This indicates that the polysemy effect which originally appeared on lexical decision latencies disappeared when a lexical access component is partialled out by using naming latency as a predictor variable. Thus, the results suggest the possibility that polysemy influences lexical access.

Since Chumbley and Balota (1984) used a dictionary count definition of polysemy, the measure of polysemy they used may be weak or inadequate as argued by Gernsbacher (1984) and Millis and Button (1989). Therefore, there still seems a possibility of obtaining the effect of polysemy on naming latencies if a stronger, more valid metric of polysemy such as the total-meaning metric or average-meaning metric is used.

In fact, Balota, et al. (1991) and Fera, Joordens, Balota, Ferraro, and Besner (1993) recently reported that they obtained polysemy effects in the naming task. The naming latencies were faster for ambiguous words than for unambiguous words. A polysemy measure used in these studies was a sort of average-meaning metric and identical to the one used in Kellas, et al. (1988). They asked subjects to rate the number of meanings for given words and nonwords on a scale which consisted of no meaning (0), one meaning (1), and more than one meaning (2).

Based on the Balota and Chumbley's (1984) arguments that naming latencies are sensitive to lexical access effects, polysemy effects on naming latencies seem to suggest that polysemy affects the lexical access process. Thus, Balota, et al. (1991) suggested a lexical access account of the polysemy effects in terms of the interactive-activation model. When the visual input is presented, word level units are activated by facilitory signals traveling through feature level and letter level units. Before the activation of a word level unit reaches its threshold, the partial activation of word level units sends facilitory signals to meaning level units. The activated meaning level units, then, send signals back down to word level units. Since ambiguous words have multiple meanings, the amount of activation in meaning level units is assumed to be greater for ambiguous words than for unambiguous words. Thus, the facilitory signals sent from meaning level to word level units are stronger for ambiguous words. Therefore, word level units for ambiguous words reach their thresholds faster than those for unambiguous words, resulting in faster lexical access for ambiguous words.

In addition to the interactive-activation account, Rubenstein and his colleagues (Rubenstein, et al., 1970; Rubenstein, et al., 1971) suggested another lexical access account of polysemy effects. They assumed frequency-ordered serial comparison processes between visual inputs and lexical entries to allow lexical access. Further, they assumed multiple lexical entries for ambiguous words and the polysemy effects were based on the difference in the number of lexical entries between ambiguous and unambiguous words. In their model, higher frequency words are compared with visual inputs faster than lower frequency words. However, within the identical frequency range, the comparison processes are assumed to occur in a random order. Therefore, words with multiple entries should have greater probability to be compared with visual inputs faster than words with fewer entries. Thus, their model assumed that polysemy, as well as frequency, affects the speed of lexical access.

Jastrzembski (1981) explained the polysemy effects in terms of Morton's (1969) logogen model. As in Rubenstein, et al.'s model, Jastrzembski assumed that ambiguous words are represented by separate logogens with one logogen for each meaning. Since more logogens are activated by ambiguous words, the probability of any one logogen reaching threshold would be greater for ambiguous words than for unambiguous words. Thus, the polysemy effects were assumed to occur due to the horse race among logogens within the frequency-sensitive lexical access mechanism.

The present studies were conducted to address the issue of whether a semantic variable has any effects on lexical access by examining the effects of polysemy in lexical decision (Experiment 1) and naming tasks (Experiment 2). The polysemy measure used in the present studies was identical to the one used in Kellas, et al. (1988). Twenty subjects were asked to rate the number of meanings for given words and nonwords on three-point scales. Based on the rating data, words rated more than 1.5 were taken as ambiguous and those rated less than 1.4 as unambiguous.

Further, care was taken to ensure "systematicity" and "equiprobability" of ambiguous words' meanings. Rubenstein, et al. (1971) examined whether "equiprobability" of meaning frequency and "systematicity" of meanings have any effects on lexical decision latencies. Meaning frequency refers to the relative frequency of occurrence of each meaning. Some ambiguous words are used more often as the dominant meanings than as the subordinate meanings. But others are used with almost equal frequency as the dominant or the subordinate meanings. Rubenstein, et al. asked 20 subjects to write down the first meaning which came to mind when given each ambiguous word. Meaning frequency for a particular meaning was calculated based on the number of subjects who generate the meaning. For example, *foot* is almost always used to mean "the object at the end of a leg" but sometimes it is used as "a unit of measurement." According to Nelson, McEvoy, Walling, and Wheeler's (1980) word association norms for ambiguous words, the "leg" meaning was given by 44 subjects out of 46. Thus, the dominant meaning frequency was .96. Similarly, the meaning frequency of the subordinate meaning was .02 because this meaning was given by only one subject. On the other hand, *change* is used to mean "money" as often as to mean "alter." The dominant and the subordinate meaning frequency of *change* based on Nelson, et al.'s norms were .54 and .46, respectively. In this way, Rubenstein, et al. manipulated the "equiprobability" of meaning frequency. Further, they manipulated the "systematicity" of meanings. There are ambiguous words whose meanings are related but differ in syntactic category such as *bomb*, *nail*, and *knife*. They called those words systematic. On the other hand, ambiguous words such as *yard*, *calf*, and *tank* have no systematic relations among their meanings. These words were called unsystematic. Their results showed that lexical decision latencies for unsystematic equiprobable ambiguous words were faster than those for any other types of words. But the latencies for other types of ambiguous words didn't differ from those for unambiguous words. Therefore, to increase the chance of obtaining polysemy effects, only the unsystematic equiprobable ambiguous words were used in the present experiments. That is, unsystematic ambiguous words were used only if the subordinate meaning frequency was more than 0.15.

Since the primary purpose of the present studies was to find the locus of the polysemy effect by comparing the results from different tasks, following Balota and Chumbley (1984, 1985), the lexical decision task was assumed to consist of the lexical access process and the postaccess decision making processes. Similarly, the naming task was assumed to consist of the lexical access process and the postaccess pronunciation-related processes. In this context, if the identical pattern of polysemy effects appears in both lexical decision and naming tasks, the effects will be regarded as occurring at the common lexical access process. But if the results differ depending on the tasks, the effects will be considered to occur at the postaccess, task-specific processes.

EXPERIMENT 1

In Experiment 1, the effects of polysemy and frequency were examined using the lexical decision task.

Method

Subjects. Twenty-six undergraduate students from the University of Western Ontario participated in this experiment. They received course credit for their participation. All were native English speakers and had normal or corrected-to-normal vision.

Stimuli. Forty ambiguous-unambiguous word pairs were created. The forty unsystematic ambiguous words were selected from Nelson, et al. (1980) and Cramer (1970). The words were selected to have meaning frequencies as equiprobable as possible, thus, all subordinate meaning frequencies for the ambiguous words were greater than .15. These words were classified into twenty high frequency words (more than 80 per million) and twenty low frequency words (less than 30 per million) by using the Kucera and Francis (1967) norms. Each ambiguous word was paired with an unambiguous word. The word frequency and the word length were matched as closely as possible. Most unambiguous words were taken from Rubenstein, et al. (1970) and Rubenstein, et al. (1971). Some others were selected from the Kucera and Francis norms based on the experimenter's intuition as to the number of meanings. After forty word pairs were collected, twenty-two subjects were asked to rate the experiential familiarity for each word. The eighty words were randomly ordered and listed in a questionnaire. Each word was accompanied by a seven-point scale from very unfamiliar (1) to very familiar (7). The subjects were asked to rate the experiential familiarity by circling the appropriate number on the scale. Further, another twenty subjects were asked to rate the number of meanings for those words. The procedure used for collecting the number-of-meanings rating data was identical to the one used by Kellas, et al. (1988). The forty ambiguous and forty unambiguous words were randomly ordered and listed in a questionnaire together with forty nonwords. At the right hand side of each item, a scale from 0 to 2 was printed. The subjects were asked to decide whether the item had no meaning (0), one meaning (1), or more than one meaning (2), by circling the appropriate number on the scale. Finally, based on the rating data, fifteen high frequency ambiguous-unambiguous word pairs and fifteen low frequency pairs were selected ensuring that the number of meaning rating values for ambiguous words were more than 1.5 and the values for unambiguous words were less than 1.4. The experiential familiarity rating values were quite comparable between ambiguous and unambiguous word groups. In addition, the mean positional bigram frequency (Mayzner & Tresselt, 1965) was equated across word groups. The orthographic neighborhood sizes were also roughly equated between ambiguous and unambiguous word groups. Thus, four word groups were created by crossing two factors, word frequency (high or low) and polysemy (ambiguous or unambiguous). The experimental word stimuli are listed in the Appendix. The statistical characteristics of these words are given in Table 1.[1]

The experimental word stimuli were 4 or 5 letters long. In addition to the experimental word stimuli, twenty filler word stimuli and eighty nonword stimuli were added. Thus, the entire stimulus set consisted of 160 stimuli. All the nonwords were pronounceable nonwords and were created by replacing one letter from actual words. The

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[1] T-tests comparing ambiguous and unambiguous word groups on word frequency, word length, orthographic neighborhood size, mean bigram frequency, experiential familiarity rating, and number of meanings rating were conducted. No significant differences were detected (word frequency: $t(28)=.05$ for high frequency, $t(28)=.07$ for low frequency; word length: $t(28)=.00$ for high frequency, $t(28)=.00$ for low frequency; orthographic neighborhood size: $t(28)=1.47$ for high frequency, $t(28)=1.47$ for low frequency; mean bigram frequency: $t(28)=.45$ for high frequency, $t(28)=.71$ for low frequency; experiential familiarity rating: $t(28)=.23$ for high frequency, $t(28)=.20$ for low frequency) except for the number of meaning rating ($t(28)=24.55$, $p<.001$ for high frequency, $t(28)=16.04$, $p<.001$ for low frequency).

Table 1

Mean Word Frequency (Freq), Word Length (Length), Orthographic Neighborhood Size (N), Bigram Frequency (BF), Experiential Familiarity Rating (FAM), Number of Meanings Rating (NOM), Dominant Meaning Frequency (DOM), and Subordinate Meaning Frequency (SUB) for the Stimuli in Each Condition.

Condition Frequency / Ambiguity	Freq	Length	N	BF	FAM	NOM	DOM	SUB
Low / Ambiguous	14.2	4.33	7.53	53.26	2.62	1.79	.50	.41
Low / Unambiguous	14.4	4.33	5.20	45.32	2 69	1.08		
High / Ambiguous	226.67	4.33	9.13	60.71	4.62	1.83	.49	30
High / Unambiguous	231.13	4.33	6.53	55.42	4.71	1.05		

Note - Mean NOM Rating for the forty nonwords was 0.016.

mean length of the nonwords was 4.40, ranging from 3 to 7. The mean length of words (experimental + filler) was 4.45, ranging from 3 to 6.

Procedure. Subjects were tested individually in a normally lit room. Subjects were asked to make a word-nonword discrimination for a stimulus appearing on a video monitor (CMS-3436, Multiscan Monitor) by pressing either the word or the nonword key. They were also told that their response should be made as quickly and as accurately as possible. Ten practice trials were given prior to the 160 experimental trials. During the practice trials, subjects were informed about their lexical decision latency and whether the response was correct after each trial. No feedback information was given during the experimental trials. The order of the stimulus presentation for the experimental trials was randomized for each subject.

Each trial was initiated with a 50 ms 400 Hz beep signal. Following the beep, a fixation point appeared at the center of the video monitor. One second after the onset of the fixation point, a stimulus was presented in capital letters above the fixation point. The fixation point and the stimulus were presented in white color at a luminance of 12 lux (as measured from a 10 mm × 10 mm square at a 0 cm distance by a United Detector Technology, Inc., UDT-40X OPTO-METER in a darkened room). Subjects were seated in front of the video monitor and asked to respond to the stimulus by pressing either the word or the nonword key on the response-box interfaced to a microcomputer (AMI 386 Mark II). The "word" response was made using the subject's dominant hand. The subject's response terminated the presentation of the stimulus and the fixation point. The lexical decision latencies from the onset of the stimulus to the subject's key press and whether the response was correct were automatically recorded by the microcomputer. The intertrial interval was three seconds.

Results

When a lexical decision latency was less than 250 ms or greater than 1500 ms, the trial was considered an error. Thus, nine data points (0.22%) were considered as errors and excluded from the analyses of lexical decision latencies. Mean lexical decision latencies for correct responses and mean error rates were calculated across subjects and items separately. The mean lexical decision latencies and error rates of word data averaged over subjects are presented in Table 2. The mean lexical decision latency and error rate for nonword trials were 686 ms and 0.06, respectively.

Subject and item means of lexical decision latencies and error rates for word data were submitted to separate analyses of variance. In the analyses of lexical decision latencies, the main effect of word frequency was significant both in the subjects' and the items' analyses ($F_S(1,25)=120.61, p<.001$; $F_i(1,56)=41.71, p<.001$) reflecting the fact that lexical decision latencies were faster for high frequency words than for low frequency words. The main effect of polysemy was also significant in the subjects' analysis ($F_S(1,25)=6.75, p<.025$) and marginally significant in the items' analysis ($F_i(1,56)=3.35$, $p<.08$). Thus, lexical decision latencies were faster for ambiguous words than for unambiguous words. The interaction between polysemy and word frequency was not significant in either analysis ($F_S(1,25)=.18, p>.10$; $F_i(1,56)=.34, p>.10$).

In the analyses of error rates, the main effect of word frequency was again significant in both analyses ($F_S(1,25)=30.54, p<.001$; $F_i(1,56)=8.72, p<.01$), reflecting the fact that responses to high frequency words were more accurate than responses to low frequency words. The main effect of polysemy was significant in the subjects' analysis ($F_S(1,25)=11.11, p<.01$) although not in the items' analysis ($F_i(1,56)=2.37, p>.10$). Further, the interaction between polysemy and word frequency was significant in the

Table 2
Mean Lexical Decision Latencies (in Milliseconds) and Error Rates in Experiment 1.

Polysemy	Word Frequency: Low	Word Frequency: High	RT difference
Ambiguous	613 (.054)	548 (.021)	+65
Unambiguous	631 (.110)	561 (.026)	+70
RT difference	+18	+13	

Notes - Error rates in parentheses (). Mean lexical decision latency and error rate for nonwords were 686 ms and 0.06, respectively.

subjects' analysis ($F_S(1,25)=7.91$, $p<.01$) although not in the items' analysis ($F_i(1,56)=1.65$, $p>.10$), reflecting a trend for the responses to ambiguous words to be more accurate than responses to unambiguous words in the low frequency word condition, whereas there was no such trend in high frequency word condition.

Discussion

Polysemy effects were observed on lexical decision latencies and error rates. That is, subjects responded more quickly and accurately for ambiguous words than for unambiguous words. Further, the interaction between polysemy and frequency wasn't significant for latency data although it was for error rates. The interaction on error rates seems to have been caused by two items in the low frequency unambiguous condition, *veto* and *sewer*. The error rates for these items were quite high, .54 and .31, respectively. By excluding these two items, the mean error rate for the low frequency unambiguous condition became .062. It was quite comparable to the error rate in the low frequency ambiguous condition (.054). Therefore, excluding these items and their paired ambiguous items (*hail* & *spade*, respectively), analyses of variance were again conducted on lexical decision latencies and error rates. In the analyses of error rates, the main effect of frequency was significant in both the subjects' and items' analyses ($F_S(1,25)=13.29$, $p<.001$; $F_i(1,52)=10.62$, $p<.01$) but neither the main effect of polysemy nor the interaction between polysemy and frequency was significant. The pattern of results on decision latencies didn't change at all regardless of the exclusion of these items. The main effect of frequency was significant in both analyses ($F_S(1,25)=91.70$, $p<.001$; $F_i(1,52)=38.51$, $p<.001$). The main effect of polysemy was significant only in the subjects' analysis ($F_S(1,25)=5.96$, $p<.025$; $F_i(1,52)=2.78$, $p>.10$), and, as before, the interaction between polysemy and frequency was not significant in either analysis ($F_S(1,25)=.04$, $p>.10$; $F_i(1,52)=.05$, $p>.10$). Thus, the results replicated those of Rubenstein, et al. (1970).

The lack of an interaction between polysemy and frequency contrasts with the results from Jastrzembski (1981). Jastrzembski obtained polysemy effects in both high and low frequency conditions, however, the size of the polysemy effects was significantly larger in the low frequency condition (143 ms) than in the high frequency condition (79 ms). Although the difference between the present results and his, with respect to the interaction between polysemy and frequency, may have been caused by uncontrolled variables, it should be noted that Jastrzembski's study and the present study differed in how polysemy was defined. Since Jastrzembski manipulated polysemy in terms of the number of dictionary definitions, as pointed out by Gernsbacher (1984), his definition might not appropriately represent the number of meanings which are really accessed. Further, his polysemy measure seems not to take into account systematicity or equiprobability of meanings. Since Rubenstein, et al.'s (1971) results indicated that these variables affect lexical decision latencies, there might be some accidental effects caused by those variables in Jastrzembski's studies.

Further, since Jastrzembski did not control the experiential familiarity, as Gernsbacher (1984) pointed out, the familiarity for ambiguous words might be higher than that for unambiguous words. Assuming a logarithmic function for the effects of familiarity, the difference in lexical decision latencies due to a particular difference in familiarity should be larger for words in the low frequency range than for words in the high frequency range. Thus it is quite possible that, in Jastrzembski's studies, when polysemy was confounded with experiential familiarity, this confound may have caused the interaction between polysemy and frequency.

However, we should also notice that, in Rubenstein, et al.'s study (1970), their post hoc analysis showed that ambiguous words with more than two meanings were responded to faster than ambiguous words with just two meanings and the effect was significantly larger in the low frequency condition than in the high frequency condition. Further, although the interaction on error rates in the present experiment seems to be explained because of the high error rates for a few items, it may still suggest a possibility that polysemy has somewhat greater impact for low frequency words than for high frequency words. If so, the present results do not necessarily contradict Jastrzembski's data.

Thus, although it is unclear whether polysemy interacts with frequency on lexical decision latencies, it seems at least possible to conclude that the polysemy effects appear for both high and low frequency words in the lexical decision task.

EXPERIMENT 2

Experiment 2 was conducted to examine whether polysemy effects on naming latencies were identical to those on lexical decision latencies. Assuming that both lexical decision and naming tasks require lexical access, if the effects of polysemy observed for lexical decision latencies also appear for naming latencies, the effects can be argued to arise during lexical access. But, as argued by Chumbley and Balota (1984), if semantic variables such as polysemy have no effect on lexical access, there should be no polysemy effects on naming latencies. Polysemy effects on lexical decision latencies would, therefore, be considered to arise during postaccess processes specific to the lexical decision task such as decision making.

Method

Subjects. Twenty-six undergraduate students from the University of Western Ontario participated in this experiment for course credit. All were native English speakers and had normal or corrected-to-normal vision. None had participated in Experiment 1.

Stimuli. The stimuli were the eighty word stimuli used in Experiment 1, the sixty experimental word stimuli in which word frequency and polysemy were orthogonally manipulated and twenty filler word stimuli.

Procedure. Subjects were tested individually. Subjects were asked to name aloud a word, which appeared on a video monitor, as quickly and as accurately as possible. Ten practice trials were given prior to the 80 experimental trials. During the practice trials, subjects were informed of their naming latency after each trial. No feedback information was given during the experimental trials. The order of the stimulus presentation for the experimental trials was randomized for each subject.

On each trial, the stimulus was presented in the same manner and at the same luminance as in Experiment 1. Subjects were asked to name a word aloud into a microphone connected to a voice key interfaced to a microcomputer. The subject's vocal responses terminated the stimulus presentation and the naming latency, from the onset of the stimulus to the onset of the subject's response, was recorded automatically. An experimenter sat behind the subject and recorded errors. The intertrial interval was three seconds.

Results

A trial was considered a mechanical error if the subject's vocal response failed to trigger the voice key or some extraneous sound triggered the voice key. The mechanical errors were excluded from the data analyses. There were 27 (1.30%) mechanical errors in total. In addition, when a reaction time was less than 250 ms or more than 1000 ms, the trial was considered an error. Nine data points (0.43%) were considered as errors and removed from the analyses of naming latencies. Mean naming latencies for correct responses and mean error rates were calculated across subjects and items separately. The mean naming latencies and error rates averaged over subjects are presented in Table 3

Subject and item means for naming latencies and error rates were submitted to separate analyses of variance. In the analyses of naming latencies, the main effect of word frequency was significant both in the subjects' and the items' analyses ($F_s(1,25)=31.73$, $p<.001$; $F_i(1,56)=8.58$, $p<.01$), reflecting the fact that naming latencies were faster for high frequency words than for low frequency words. The main effect of polysemy was

Table 3
Mean Naming Latencies (in Milliseconds) and Error Rates in Experiment 2.

	Word Frequency		
Polysemy	Low	High	RT difference
Ambiguous	469 (.036)	457 (.010)	+12
Unambiguous	489 (.042)	458 (.013)	+31
RT difference	+20	+ 1	

Note - Error rates in parentheses ().

significant in the subjects' analysis ($F_s(1,25)=21.50$, $p<.001$) although not in the items' analysis ($F_i(1,56)=1.59$, $p>.10$). Thus, there was a trend for naming latencies to be faster for ambiguous words than for unambiguous words In addition, the interaction between polysemy and word frequency was significant in the subjects' analysis ($F_s(1,25)=7.34$, $p<.025$) although not in the items' analysis ($F_i(1,56)=1.41$, $p>.10$). Newman-Keuls tests (based on subject means) were used to examine the difference between ambiguous and unambiguous words for each frequency condition. The polysemy effect was significant for low frequency words ($q(2,25)=5.70$, $p<.01$) but not for high frequency words ($q(2,25)=.28$).

In the analyses of error rates, the only significant effect was the main effect of word frequency in both analyses ($F_s(1,25)=16.45$, $p<.001$; $F_i(1,56)=5.77$, $p<.025$). Thus, the responses to high frequency words were more accurate than those to low frequency words. Neither the main effect of polysemy ($F_s(1,25)=.25$, $p>.10$; $F_i(1,56)=.12$, $p>.10$) nor the interaction between polysemy and word frequency ($F_s(1,25)=.02$, $p>.10$, $F_i(1,56)=.01$, $p>.10$) was significant in either analysis.

Discussion

Polysemy affected naming latencies and, further, the interaction between polysemy and frequency was significant. Polysemy effects appeared only for low frequency words Thus, although polysemy affected naming as well as lexical decision latencies, the patterns of results that appeared were task-specific. The effects of polysemy were additive with frequency in the lexical decision task, whereas they were interactive in the naming task. There are several possibilities for explaining these results but, at least, it seems impossible to explain these results by assuming a single locus of polysemy effects. If the effects of polysemy as well as frequency were due only to the lexical access process which is common to both tasks, the results should have been identical in the two tasks. If the effects were due only to postaccess processes specific to the lexical decision task, the effects should only have appeared in the lexical decision task. The reverse should have been true if the effects were due only to postaccess processes specific to the naming task. Thus, the results from both experiments clearly deny single locus accounts of polysemy effects. Therefore, there must be at least two processes which are responsible for polysemy effects.

First, let us assume that the lexical access process and the decision making processes in the lexical decision task are both influenced by polysemy. As Balota and Chumbley (1984) suggested, if naming latency is a better measure of lexical access than lexical decision latency and, thus, reflects the effects which occur during lexical access more directly, we could argue that the interactive pattern of results between polysemy and frequency on naming latencies occurred during lexical access. In other words, polysemy can be considered to affect the speed of lexical access only for low frequency words. Since lexical decision latencies were assumed to consist of lexical access and postaccess, task-specific components, the additive pattern of results between polysemy and frequency on lexical decision latencies should also contain the effects due to lexical access. Therefore, the task-specific component should be what produced the polysemy effects for high frequency words. That is, assuming that polysemy influences the lexical access process and the processes specific to the lexical decision task, the results from two experiments would suggest that low frequency words are affected by polysemy at the lexical access level whereas high frequency words are affected at the postaccess level. In order to complete the explanation, the additional assumption could be made that accessing semantic representations is done independent of lexical access but takes a reasonable amount of time. Since the speed of lexical access is assumed to be faster for high frequency words than for low frequency words, lexical access for high frequency words may be accomplished before any semantic information becomes available. On the other hand, since lexical access for low frequency words is assumed to be relatively slow, semantic information may be available before lexical access is completed. Thus, the effects of polysemy may occur for low frequency words. In the lexical decision task, however, the decision making processes have to be carried out after lexical access is accomplished. The decision latencies are, thus, longer than naming latencies for both high and low frequency words. Therefore, there may be enough time for semantic information to become available before the lexical decision responses are made, regardless of word frequency. Thus, polysemy effects would appear for both high and low frequency words.

Another possibility to resolve the discrepancy between the results from the two experiments is to assume that polysemy affects each task-specific component independently. That is, polysemy would be assumed to affect the postaccess decision making processes in the lexical decision task and the postaccess pronunciation-related processes in the naming task. The additive relationship between polysemy and frequency may be due to the decision making processes in lexical decision, whereas the interactive relationship between these variables may be due to the pronunciation-related processes in naming. Although, at this point, it is unclear why these different processes produce the differential relationships between polysemy and frequency, it seems, nonetheless, possible to assume that the postaccess processes specific to each task are responsible for the inconsistent results between lexical decision and naming.

In Experiment 3, these two hypotheses were examined using a go-no go naming task which seems to require both decision making processes and pronunciation-related processes after lexical access is accomplished.

EXPERIMENT 3

The two possible accounts for the inconsistent results between lexical decision and naming differ in the way they explain the results from the naming task. The former account assumed that the results from the naming task reflect the effects occurring during lexical access. Thus, the interaction between polysemy and frequency effects which appeared on naming latencies were lexical effects. On the other hand, the latter account assumed that there is no effect of polysemy during lexical access. Rather, the effects on naming latencies are due to the postaccess processes specific to the naming task.

These different explanations can be examined in a go-no go naming task. The go-no go naming task is a variation of the lexical decision task in which overt pronunciations are required only for word stimuli. That is, subjects are asked to read a stimulus aloud only when the stimulus is a word. According to the former account of the difference between Experiments 1 and 2, a key variable is the processing time before making a response. Since the go-no go naming task is essentially identical to the lexical decision task except in the way subjects respond to the stimuli, this task also requires the postaccess decision making processes. Thus, in both tasks, there should be enough time for semantic representations to become available before a response is made. Thus, polysemy effects should appear for both high and low frequency words in the go-no go naming task as in the standard lexical decision task. On the other hand, if the interactive pattern of results on naming latencies is due to the postaccess, task-specific processes, the go-no go naming task should also produce the interaction between polysemy and frequency. That is, assume that the go-no go naming task consisted of the following components in the following sequence: lexical access - decision making processes - pronunciation-related processes. After lexical access is accomplished, a word-nonword decision would be made. At this point, polysemy is assumed to affect the decision making processes in the same way as in the lexical decision task. That is, polysemy should be additive with frequency. In addition, when the stimulus is a word, the pronunciation-related processes have to be carried out to produce an overt pronunciation These processes, as in the naming task, are assumed to produce an interaction between polysemy and frequency. Therefore, the final response latencies for word stimuli should show an interaction between polysemy and frequency. Thus, polysemy effects should appear both for low and high frequency words and the size of polysemy effects should be larger for low frequency words than for high frequency words. In Experiment 3, therefore, a go-no go naming task was conducted using the identical stimuli used in Experiment 1.

Method

Subjects. Thirty undergraduate students from the University of Western Ontario participated in this experiment for course credit. All were native English speakers who had normal or corrected-to normal vision. None had participated in previous experiments.

Stimuli. The stimuli were the same as used in Experiment 1. The word stimuli consisted of the sixty experimental word stimuli, in which word frequency and polysemy were orthogonally manipulated, and twenty filler word stimuli. There were also eighty nonword stimuli, all of which were pronounceable.

Procedure. Subjects were tested individually. Subjects were asked to name a stimulus aloud into a microphone only if the stimulus was a word. They were also told that their responses should be as quick and as accurate as possible. Ten practice trials were given prior to the 160 experimental trials. During the practice trials, subjects were informed of their reaction time and whether the response was correct after each trial. No feedback information was given during the experimental trials. The order of the stimulus presentations for the experimental trials was randomized for each subject.

The stimuli were presented in the same manner and at the same luminance as in Experiment 1. The stimulus remained on the video monitor either until the subject responded or until two seconds had elapsed. The subjects' task was to name the stimulus aloud into a microphone connected to a voice key only if it was a word. The response latencies from the onset of the stimulus to the onset of the subjects' responses were recorded automatically. An experimenter sat behind the subject and recorded errors. The intertrial interval was three seconds.

Results

A trial was considered a mechanical error if the subject's vocal response failed to trigger the voice key or some extraneous sound triggered the voice key. The mechanical errors were excluded from the data analyses. There were 51 (2.13%) mechanical errors in total. Further, when a response latency was less than 250 ms or greater than 1600 ms, the trial was considered an error and excluded from the analyses of response latencies. For this reason, 11 data points (0.45%) were removed from the analyses of response latencies. Mean response latencies for correct responses and mean error rates were calculated across subjects and items separately. The mean response latencies and error rates of the word data averaged over subjects are presented in Table 4. The mean error rate of the nonword data was 0.03.

Subject and item means of response latencies and error rates were submitted to separate analyses of variance. In the analysis of response latencies, the main effect of word frequency was significant both in the subjects' and the items' analyses ($F_S(1,29)=111.97$,

Table 4
Mean Response Latencies (in Milliseconds) and Error Rates in Experiment 3.

	Word Frequency		
Polysemy	Low	High	RT difference
Ambiguous	661 (.023)	577 (.004)	+84
Unambiguous	702 (.056)	595 (.004)	+107
RT difference	+41	+18	

Notes - Error rates in parentheses (). Mean error rate for nonwords was 0.03.

$p<.001$; $F_i(1,56)=37.44$, $p<.001$), reflecting the fact that response latencies were faster for high frequency words than for low frequency words. The main effect of polysemy was significant in the subjects' analysis ($F_s(1,29)=29.96$, $p<.001$) and marginally significant in the items' analysis ($F_i(1,56)=3.66$, $p<.07$). Thus, response latencies were faster for ambiguous words than for unambiguous words. Further, the interaction between polysemy and word frequency was significant in the subjects' analysis ($F_S(1,29)=5.54$, $p<.05$) although not in the items' analysis ($F_i(1,56)=.60$, $p>.10$). Newman-Keuls tests (based on subject means) were used to examine the difference between ambiguous and unambiguous words for each frequency condition. The polysemy effect was significant not only for low frequency words ($q(2,29)=8.55$, $p<.01$) but also for high frequency words ($q(2,29)=3.84$, $p<.05$). Thus, the interaction between polysemy and frequency suggests that polysemy had a larger effect for low frequency words than for high frequency words.

In the analyses of error rates, the main effect of word frequency was significant in both analyses ($F_s(1,29)=27.78$, $p<.001$; $F_i(1,56)=7.64$, $p<.01$), reflecting the fact that responses for high frequency words were more accurate than those for low frequency words. The main effect of polysemy was significant in the subjects' analysis ($F_s(1,25)=6.09$, $p<.025$) although not in the items' analysis ($F_i(1,56)=1.83$, $p>.10$). The interaction between polysemy and word frequency was significant in the subjects' analysis ($F_s(1,29)=4.52$, $p<.05$) although not in the items' analysis ($F_i(1,56)=1.79$, $p>.10$).

Discussion

Polysemy effects appeared for both high and low frequency words in the go-no go naming task. In addition, a significant interaction between polysemy and frequency was observed. That is, the size of the polysemy effect for low frequency words was larger than for high frequency words. Thus, the results support the claim that the polysemy effects on naming latencies (observed in Experiment 2) are due to the postaccess, task-specific processes. More concretely, the sizes of the polysemy effects obtained in the present experiment were approximately equal to the sum of the effects appearing in the lexical decision and naming tasks. For low frequency words, a 41 ms polysemy effect was observed in the present experiment, which is almost equal to the sum of the 18 ms effect in lexical decision (Experiment 1) and the 20 ms effect in naming (Experiment 2). Similarly, for high frequency words, the 18 ms polysemy effect in the present experiment was close to the 13 ms effect in lexical decision (Experiment 1) plus the 1 ms effect in naming (Experiment 2). If some portion of polysemy effects are localized at the lexical access process, the sum of the polysemy effects between lexical decision and naming should be larger than the effects in the go-no go naming task because summing the effects in lexical decision and those in naming should add the lexical access component twice. Thus, based on the results from the present experiment, it seems reasonable to conclude that the polysemy effects that appeared in the lexical decision task arose during the postaccess decision making processes. Similarly, the polysemy effects that appeared in the naming task were due to the postaccess pronunciation-related processes. Since the results strongly suggest that the polysemy effects were due to the postaccess processes specific to each task, the results are inconsistent with previous lexical access accounts of polysemy effects (Rubenstein, et al.'s model, 1970, 1971; Jastrzembski's model, 1980; Balota, et al.'s interactive-activation model, 1991).

Interestingly, the results from three experiments also seem to contradict a lexical access account of frequency effects. Rather, the results seem to indicate that frequency effects also occurred during the postaccess, task-specific processes. Similar to the polysemy effects, the sizes of frequency effects in the present experiment were approximately equal to the sum of the frequency effects observed in lexical decision and in naming (for ambiguous words: 84 ms ≑ 65 ms + 12 ms; for unambiguous words: 107 ms

≑ 70 ms + 31 ms). These facts seem to suggest the possibility that frequency effects are only minimal during lexical access and, rather, the effects are mostly due to the postaccess, task-specific processes.

As argued by Balota and Chumbley (1984), frequency effects in lexical decision might be localized at the decision making processes based on orthographic familiarity. In naming, there seem to be two possibilities for the locus of the postaccess frequency effects. Balota and Chumbley (1985) and Seidenberg and McClelland (1989) argued that the naming task consisted of three postaccess components in addition to lexical access: after completion of the lexical access process, 1) phonological representations are retrieved, 2) the retrieved phonological representations are translated to articulatory programs, and 3) the articulatory programs are executed to produce overt pronunciation responses. Balota and Chumbley (1985) obtained frequency effects in delayed naming conditions as well as in the standard naming condition. In delayed naming conditions, subjects were asked to wait to pronounce a presented word aloud until a pronunciation cue appeared. In .his situation, lexical access and the retrieval of phonological representations should have already been accomplished. Therefore, any effects appearing in this condition are considered to be due to the production processes in which the phonological representations are translated to articulatory programs and the articulatory programs are executed to produce overt pronunciations. Since Balota and Chumbley obtained word frequency effects in delayed cue conditions, they argued that a part of the frequency effects observed in standard naming tasks may also be due to the production processes. Thus, one possibility is that the locus of the frequency effects as well as the polysemy effects obtained in the naming task may occur at such production processes.

A specific proposal for which of these processes is most important was given by McCann and Besner (1987). They suggested that frequency effects in the naming task may occur during the process of retrieving phonological representations. That is, McCann and Besner suggested that frequency effects occur not because of lexical representations themselves but because of the connections between those representations and phonological representations. Their claim was based on naming latencies for pseudohomophones. The frequency of the original words from which pseudohomophones were created (base word frequency) did not affect naming latencies for pseudohomophones, although frequency effects did appear in naming latencies for the base words. Based on these findings, they argued that since phonological representations for base words and for pseudohomophones are identical and, further, only words should have orthographic lexical representations, phonological representations must be frequency-insensitive. They further argued that it seems parsimonious to assume that orthographic representations are also frequency insensitive. Given these assumptions, they concluded that the locus of the frequency effects must be the connections between orthographic and phonological representations. Similarly, in parallel distributed processing (PDP) models of word recognition (e.g., Seidenberg and McClelland, 1989; Brown, 1990), frequency effects arise due to the computations from the orthographic input to phonological output. In these models, the weights on connections between orthographic input units and phonological output units (via hidden units) reflect the frequency of experience with the words during the training phase.

Thus, both McCann and Besner (1987) and the PDP models seem to suggest that frequency effects occur during the retrieval of phonological representations. Together with Balota and Chumbley's (1985) claim that a part of frequency effects is due to the production processes, it seems possible to argue that the frequency effects observed in the present three experiments are also due to these postaccess processes instead of assuming frequency-sensitive lexical representations.

At this point, polysemy, as well as frequency, seems to have little effect during lexical access. Rather, the effects seem to be due to postaccess, task-specific processes. The next step would be to propose mechanisms for these effects by considering the essential differences between the task-specific processes which are responsible for the differential patterns of results between polysemy and frequency. Primarily, lexical decision making processes differ from pronunciation-related processes in the operations carried out on representations. Secondarily, the type of representations used in these processes also seem to be different depending on the task purpose.

Seidenberg and his colleagues (Seidenberg, 1985; Seidenberg, 1989; Waters & Seidenberg, 1985; Seidenberg & McClelland, 1989) have argued that there is a difference between naming and lexical decision in terms of the types of representations used to accomplish these tasks. Since the naming task requires production of the correct pronunciations, the task explicitly requires subjects to retrieve a phonological representation. On the other hand, it seems less likely that the lexical decision task requires subjects to retrieve phonological representations because the task does not require overt pronunciations. Rather, similar to Balota and Chumbley's (1984) model of the lexical decision task, Seidenberg and his colleagues argued that lexical decisions would usually be made based on the orthographic representations of stimuli if the orthographic information provides enough of a clue to discriminate words from nonwords. For example, when unpronounceable random letter strings (e.g., DPKW) were used as nonwords (e.g., James, 1975), or when there were detectable differences in orthographic properties between words and nonwords such as string length (e.g., Chumbley & Balota, 1985), lexical decisions would be made based simply on orthographic information. However, when orthographic properties do not provide any reliable clue for the decision, subjects may retrieve phonological representations of the stimuli if the phonological information provides clues for the discrimination (e.g., Waters & Seidenberg, 1985).

The empirical support for this view was provided by studies concerning the effects of regularity of spelling-sound correspondences. English words can be categorized in terms of the correspondence between spelling and sound. Some words rhyme with all other words which share similar spelling patterns. In such words, the spelling patterns systematically map to their pronunciations based on the spelling-sound correspondence rules (Venezky, 1970). These words (e.g., *take* rhymes with *make*, *cake*, *bake*, etc.) are termed regular words. At the same time, there are some English words which violate the rules of correspondences (e.g., *have* violates the rules established in *gave*, *save*, *cave*, etc.). These are termed exception words.

A number of studies (e.g., Andrews, 1982; Baron & Strawson, 1976; Coltheart, Besner, Jonasson, & Davelaar, 1979; Glushko, 1979; Seidenberg, Waters, Barnes, & Tanenhaus, 1984; Stanovich & Bauer, 1978; Waters & Seidenberg, 1985) have shown that naming latencies for exception words are longer than those for regular words. Further, Andrews (1982) and Seidenberg, et al. (1984) found that this difference in naming latencies between regular and exception words is limited to low frequency words. On the other hand, although these regularity effects have been consistently found in naming tasks, the results from lexical decision tasks have been inconsistent. Some studies (e.g., Bauer & Stanovich, 1980; Parkin, 1982; Parkin & Underwood, 1983) obtained regularity effects in lexical decisions but others (e.g., Andrews, 1982; Coltheart, et al., 1979) failed to obtain the effects. Waters and Seidenberg (1985) attempted to resolve this inconsistency. What they found was that the regularity of spelling-sound correspondences had effects on lexical decision latencies only when the stimulus set contained "strange" words, which had uncommon spelling patterns such as *aisle*, *sign*, *gauge*, etc. That is, without strange words in the stimulus set, they obtained no effects of regularity on lexical decision latencies.

Waters and Seidenberg argued that including strange words which have orthographically uncommon spelling patterns in the stimulus set made orthographically based word-nonword discriminations difficult because including these words increased the overlap between word and nonword distributions on an orthographic familiarity dimension (e.g., Balota & Chumbley, 1984). Because of the difficulty of the orthographically based discriminations, subjects had to use phonological information for the stimuli to make word-nonword discriminations possible. Thus, regularity effects appeared because the decision processes were now carried out based on phonological representations of the stimuli.

Thus, it seems possible to propose that lexical decisions are usually made based on orthographic information if orthographic properties of the stimuli provide enough of a clue to discriminate words from nonwords, whereas naming always necessitates the retrieval of phonological information because overt pronunciations are required. If such is the case, the differential patterns of results between lexical decision and naming in the present studies may be due to the type of representations used in the task-specific processes.

According to Seidenberg and his colleagues' argument about the type of representations used in the lexical decision task, subjects seem to change their response strategy and use phonological information as the basis for decisions when orthographic familiarity of words and nonwords are similar. If such is the case, it may also be possible to bias subjects to use phonological representations in other ways, in particular, by using degraded stimuli in the lexical decision task. Since stimulus degradation seems to reduce the availability of orthographic information, word stimuli should seem less word-like. As a consequence, orthographic familiarity differences between words and nonwords should decrease and word-nonword discriminations should be somewhat more difficult to make solely on the basis of the orthographic familiarity. As such, subjects should be biased to use phonological information as the basis for the decisions. If so, and if the interaction between polysemy and frequency was because of the use of phonological representations, the interaction should be obtained even in a lexical decision task when the stimuli are degraded. On the other hand, stimulus degradation should not affect the type of representations used in a naming task because, regardless of stimulus quality, the naming task does require the retrieval of phonological representations to produce overt pronunciations. Therefore, in a naming task, the interaction between polysemy and frequency should appear regardless of stimulus quality. Thus, a lexical decision task (Experiment 4) and a naming task (Experiment 5) were conducted with degraded stimuli to address this issue.

EXPERIMENT 4

Method

Subjects. Thirty undergraduate students from the University of Western Ontario participated in this experiment for course credit. All were native English speakers and had normal or corrected-to-normal vision. None had participated in any of the previous experiments.

Stimuli. The stimuli were the same as used in Experiment 1. In this experiment, however, all stimuli were presented in a degraded intensity on a video monitor. The degradation was done by reducing the voltage on the red, green, and blue signals of an analog video monitor through Digital to Analog Converter (DAC) register programming (Kliewer, 1988). The luminance of the stimuli was measured in a darkened room from a 10 mm × 10 mm square at a 0 cm distance by a United Detector Technology, Inc., UDT-40X OPTO-METER. All the stimuli were presented at a luminance of 0.036 lux just above a fixation point. The fixation point was located at the center of the video monitor at a luminance of 0.10 lux.

Procedure. Subjects were tested individually in a darkened room. The procedure was identical to Experiment 1 except that the luminance of the stimuli on a video monitor was reduced.

Results

A trial was considered an error if the lexical decision latency was less than 250 ms or more than 2000 ms. Since four subjects showed too many errors (more than 15%), their data were excluded from the data analyses. Thus, the data from 26 subjects were submitted to the analyses. For the 26 subjects' data, 5 data points (0.95%) were out of the allowable range mentioned above. Thus, these were regarded as errors and excluded from the analyses of latencies. Mean lexical decision latencies for correct responses and mean error rates were calculated across subjects and items separately. The mean lexical decision latencies and error rates of the word data averaged over subjects are presented in Table 5. The mean lexical decision latency and error rate of the nonword data were 855 ms and 0.06, respectively.

Subject and item means of decision latencies and error rates for word data were submitted to separate analyses of variance. In the analyses of decision latencies, the main effect of word frequency was significant both in the subjects' and items' analyses ($F_S(1,25)=49.51$, $p<.001$; $F_i(1,56)=28.76$, $p<.001$) reflecting the fact that lexical decision latencies were faster for high frequency words than for low frequency words. The main effect of polysemy was significant in the subjects' analysis ($F_S(1,25)=4.51$, $p<.05$) although not in the items' analysis ($F_i(1,56)=1.48$, $p>.10$). The interaction between polysemy and word frequency was also significant in the subjects' analysis ($F_S(1,25)=8.90$, $p<.01$) although not in the items' analysis($F_i(1,56)=1.68$, $p>.10$). Newman-Keuls tests (based on subject means) were used to examine the difference between ambiguous and unambiguous words for each frequency condition. The polysemy effect was significant for low frequency words ($q(2,25)=5.63$, $p<.01$) but not for high frequency words ($q(2,25)=.34$). Thus, the interaction between polysemy and frequency suggests that polysemy effects were limited to low frequency words.

In the analyses of error rates, the main effect of word frequency was again significant in both analyses ($F_S(1,25)=22.94$, $p<.001$; $F_i(1,56)=16.47$, $p<.001$), reflecting the fact that responses to high frequency words were more accurate than those to low

Table 5
Mean Lexical Decision Latencies (in Milliseconds) and Error Rates in Experiment 4.

	Word Frequency		
Polysemy	Low	High	RT difference
Ambiguous	779 (.064)	715 (.013)	+64
Unambiguous	819 (.105)	713 (.031)	+106
RT difference	+40	- 2	

Notes - Error rates in parentheses (). Mean lexical decision latency and error rate for nonwords were 855 ms and 0.06, respectively.

frequency words. The main effect of polysemy was significant in the subjects' analysis ($F_s(1,25)=4.86$, $p<.05$) and marginally significant in the items' analysis ($F_i(1,56)=3.63$, $p<.07$), indicating that responses were more accurate for ambiguous words than for unambiguous words. The interaction between polysemy and word frequency was not significant in either analysis ($F_s(1,25)=.60$, $p>.10$; $F_i(1,56)=.56$, $p>.10$).

To examine the effects of stimulus quality on lexical decision latencies, combined analyses with the data from Experiment 1 were examined. The subject and item means of lexical decision latencies and error rates from Experiment 1 and 4 were submitted to 2 (word frequency) × 2 (polysemy) × 2 (stimulus quality) analyses of variance separately. In the subjects' analyses, word frequency and polysemy were within-subject factors while stimulus quality was a between-subject factor. In the items' analyses, word frequency and polysemy were between-item factors while stimulus quality was a within-item factor.

In the analyses of decision latencies, the main effect of stimulus quality was significant in both analyses ($F_s(1,50)=89.47$, $p<.001$; $F_i(1,56)=705.32$, $p<.001$), reflecting the fact that lexical decision latencies were slower for degraded stimuli. The main effect of frequency was also significant in both analyses ($F_s(1,50)=126.38$, $p<.001$; $F_i(1,56)=40.31$, $p<.001$). The main effect of polysemy was significant in the subjects' analysis ($Fs(1,50)=10.34$, $p<.01$) although not in the items' analysis ($F_i(1,56)=2.56$, $p>.10$). The two-way interaction between polysemy and frequency was also significant in the subjects' analysis ($F_s(1,50)=6.66$, $p<.025$) although not in the items' analysis ($F_i(1,56)=1.23$, $p>.10$). Further, the three-way interaction between polysemy, frequency, and stimulus quality was significant in the subjects' analysis ($F_s(1,50)=4.19$, $p<.05$) although not in the items' analysis ($F_i(1,56)=1.44$, $p>.10$). Neither the interaction between frequency and stimulus quality ($F_s(1, 50)=1.72$, $p>.10$; $F_i(1,56)=2.07$, $p>.10$) nor the interaction between polysemy and stimulus quality ($F_s(1,50)=.09$, $p>.10$; $F_i(1, 56)=.00$, $p>.10$) were significant in either analysis. The significant three-way interaction was presumably due to the polysemy effect being additive with frequency when clear stimuli were used, whereas polysemy interacted with frequency when the stimuli were degraded.

In the analyses of error rates, the main effect of frequency was significant in both analyses ($F_S(1,50)=51.88$, $p<.001$; $F_i(1,56)=14.72$, $p<.001$). The main effect of polysemy was significant in the subjects' analysis ($F_S(1,50)=13.75$, $p<.001$) and marginally significant in the items' analysis ($F_i(1,56)=3.60$, $p<.07$). The two-way interaction between frequency and polysemy was significant in the subjects' analysis ($F_S(1,50)=4.53$, $p<.05$) although not in the items' analysis ($F_i(1,56)=1.37$, $p>.10$). All other effects were nonsignificant (all Fs<1).

Discussion

The interaction between polysemy and word frequency appeared in lexical decision when the stimuli were degraded. The effect of polysemy was limited to low frequency words. The significant three-way interaction between polysemy, frequency, and stimulus quality in the combined analysis clearly reflected the fact that the interactior between polysemy and frequency appeared when the stimuli were degraded whereas polysemy was additive with frequency when clear stimuli were used. Further, the results in the present experiment were quite similar to those observed in a naming task (Experiment 2). In both experiments, the polysemy effect was limited to low frequency words. Further, note that in both experiments the size of the frequency effect for unambiguous words (31 ms in Experiment 2; 106 ms in Experiment 4) was approximately twice as large as that for ambiguous words (12 ms in Experiment 2; 64 ms in Experiment 4). On the other hand, when clear stimuli were used in lexical decision (Experiment 1), the size of the frequency effects was approximately the same for ambiguous (65 ms) and unambiguous words (70 ms).

Based on these similarities between the results of the present experiment and those of the naming task, it seems quite likely that stimulus degradation biased subjects to use phonological representations and that the decisions were made based on the phonological information for degraded stimuli whereas subjects' decisions had been based on orthographic information when the clear stimuli were used.

A number of studies have shown that frequency is additive with stimulus quality in lexical decision tasks (Becker & Killion, 1977; Stanners, Jastrzembski, & Westbrook, 1975; Wilding, 1988). That is, the size of frequency effects was identical regardless of stimulus quality. The present experiment replicated these findings only for ambiguous words. For ambiguous words, the sizes of frequency effects were almost the same for clear (65 ms) and degraded stimuli (64 ms). On the other hand, for unambiguous words, the size of the frequency effect for degraded stimuli (106 ms) was much larger than that for clear stimuli (70 ms). These differences were reflected in the three-way interaction between polysemy, frequency, and stimulus quality. Thus, contrary to the previous research, the theoretical independence between frequency and stimulus quality appears to be qualified by the results of the present studies.

Finally, assuming that stimulus degradation biased subjects to retrieve phonological representations, the interaction between polysemy and frequency was considered to be due to the use of phonological representations during the postaccess decision making processes. If such is the case, the interaction obtained for naming latencies is presumably not due to the production processes because the same interaction was also observed in the lexical decision task, a task which does not require overt pronunciations. That is, the interaction appeared even without the production processes (the process of translating phonological representations to articulatory programs and the process of executing the programs to produce overt pronunciations). Thus, the interaction between polysemy and frequency seems rather to be due to the process of retrieving phonological representations.

EXPERIMENT 5

Given the apparent differences in performance between clear and degraded stimuli in lexical decision, the effects of stimulus degradation on naming latencies were examined in Experiment 5. If these differences on lexical decision latencies were based on the different representations used in each stimulus quality condition, there should be no essential differences in naming performance caused by stimulus quality, because, regardless of stimulus quality, the naming task requires subjects to retrieve phonological representations to produce overt pronunciations. Therefore, if the interaction between polysemy and frequency observed in Experiments 2 and 4 was due to the use of phonological representations, the same interaction should also appear in a naming task with degraded stimuli. Thus, the effects of stimulus degradation in a naming task were examined using the identical stimuli used in Experiment 2.

Method

Subjects. Thirty undergraduate students from the University of Western Ontario participated in this experiment for course credit. All were native English speakers and had normal or corrected-to-normal vision. None had participated in any of the previous experiments.

Stimuli. The stimuli were the same as used in Experiment 2. As in Experiment 4, all the stimuli were presented in a degraded intensity on a video monitor. The intensity of the stimuli was identical to that in Experiment 4.

Procedure. Subjects were tested individually in a darkened room. The procedure was identical to that in Experiment 2 except that the luminance of the stimuli on a video monitor was reduced.

Results

A trial was considered a mechanical error if the subject's vocal response failed to trigger the voice key or some extraneous sound triggered the voice key. The mechanical errors were excluded from the data analyses. Further, a trial was considered an error if the naming latency was less than 250 ms or more than 1300 ms. Since four subjects showed too many errors (more than 15%), their data were excluded from the analyses. Thus, the data from 26 subjects were submitted to the analyses. For the 26 subjects' data, there were 30 (1.44%) mechanical errors in total and 15 data points (0.72%) were out of the allowable range mentioned above. Mean naming latencies for correct responses and mean error rates were calculated across subjects and items separately. The mean naming latencies and error rates averaged over subjects are presented in Table 6.

Subject and item means of naming latencies and error rates were submitted to separate analyses of variance. In the analyses of naming latencies, the main effect of word frequency was significant both in the subjects' and items' analyses ($F_S(1,25)=54.67$, $p<.001$; $F_i(1,56)=20.36$, $p<.001$) reflecting the fact that naming latencies were faster for high frequency words than for low frequency words. The main effect of polysemy was not significant in either analysis ($F_S(1,25)=2.71$, $p>.10$; $F_i(1,56)=$.[illegible], $p>.10$). The interaction between polysemy and word frequency was significant in the subjects' analyses ($F_S(1,25)=4.84$, $p<.05$) although not in the items' analysis ($F_i(1,56)=1.69$, $p>.10$). Newman-Keuls tests (based on subject means) were used to examine the difference between ambiguous and unambiguous words for each frequency condition. The polysemy

Table 6
Mean Naming Latencies (in Milliseconds) and Error Rates in Experiment 5.

	Word Frequency		
Polysemy	Low	High	RT difference
Ambiguous	663 (.051)	622 (.034)	+41
Unambiguous	690 (.037)	612 (.021)	+78
RT difference	+27	- 10	

Note - Error rates in parentheses ().

effect was significant for low frequency words ($q(2,25)=3.23$, $p<.05$) but not for high frequency words ($q(2,25)=1.17$). Thus, the interaction between polysemy and frequency suggests that the naming latencies were faster for ambiguous words than for unambiguous words only in the low frequency condition.

In the analyses of error rates, the main effect of polysemy was marginally significant in the subjects' analysis ($F_S(1,25)=3.13$, $p<.09$). No other effects were significant (all Fs<2.6).

Similar to Experiment 4, combined analyses were conducted with the data from Experiment 2 to examine the effects of stimulus quality on naming latencies. The 2 (word frequency) × 2 (polysemy) × 2 (stimulus quality) analyses of variance were carried out for subject and item means of naming latencies and error rates separately. In the subjects' analyses, word frequency and polysemy were within-subject factors while stimulus quality was a between-subject factor. In the items' analyses, word frequency and polysemy were between-item factors while stimulus quality was a within-item factor.

In the analyses of naming latencies, the main effect of stimulus quality was significant in both analyses ($F_S(1,50)=66.09$, $p<.001$; $F_i(1,56)=856.54$, $p<.001$), reflecting the fact that naming latencies were slower for the degraded stimuli. The main effect of frequency was also significant in both analyses ($F_S(1,50)=82.45$, $p<.001$; $F_i(1,56)=20.90$, $p<.001$). The main effect of polysemy was significant in the subjects' analysis ($F_S(1,50)=11.19$, $p<.01$) although not in the items' analysis ($F_i(1,56)=1.33$, $p>.10$). The interaction between frequency and stimulus quality was significant in both analyses ($F_S(1,50)=18.72$, $p<.001$; $F_i(1,56)=10.64$, $p<.01$), reflecting the fact that frequency effects were larger when the stimuli were degraded. The interaction between polysemy and frequency was significant in the subjects' analysis ($F_S(1,50)=9.45$, $p<.01$) although not in the items' analysis ($F_i(1,56)=2.12$, $p>.10$). Any other effects were nonsignificant (all Fs<1). The significant interaction between polysemy and frequency indicated that polysemy effects appeared only for low frequency words regardless of stimulus quality

In the analyses of error rates, a main effect of frequency was significant in both analyses ($F_S(1,50)=12.47$, $p<.001$; $F_i(1,56)=4.52$, $p<.05$). No other effects were significant (all Fs<2.6).

Discussion

The results from the present experiment were quite similar to those from Experiments 2 and 4. Polysemy interacted with frequency, in that polysemy effects were limited to low frequency words. Note also that as in Experiment 2, the size of the frequency effect for unambiguous words (78 ms) was twice as large as that for ambiguous words (41 ms). Thus, when the stimuli were degraded, polysemy interacted with frequency regardless of task type, but when clear stimuli were used, the interaction appeared only in the naming task and polysemy was additive with frequency in the lexical decision task. These results clearly indicate that the interactive relationship between polysemy and frequency is neither specific to a particular task nor specific to a particular stimulus quality. Thus, two different patterns of results appeared in identical tasks (Experiment 1 vs. Experiment 4) and identical results were observed in different tasks (Experiments 2 & 5 vs. Experiment 4). Since the relationship between polysemy and frequency is independent of task type, the effects should not be attributed to the operations in the postaccess processes specific to each task. If cognitive processes can be described in terms of the operations and representations, the differential patterns of results appear to be due to the difference in representations used in such processes. In particular, it seems likely that stimulus degradation biases subjects to use phonological representations which produce the interaction even in the lexical decision task.

In addition to the significant interaction between polysemy and frequency, the interaction between frequency and stimulus quality was significant in the combined analysis of naming latencies. Besner and McCann (1987) obtained a similar pattern of results using case alternated stimuli (e.g., LoSt). The effect of case alternation was larger for low frequency words than for high frequency words in the naming task, whereas case alternation didn't interact with frequency in the lexical decision task. Without regarding the polysemy factor, the present data showed that the interaction between frequency and stimulus quality was not significant in the analysis of lexical decision latencies but it was significant in the analysis of naming latencies. Further, in the naming data, the effect of stimulus quality was larger for low frequency words than for high frequency words. Together with the results from Besner and McCann's studies, frequency seems to interact with stimulus quality or with case alternation in naming tasks. Thus, these facts may suggest that frequency interacts with stimulus quality when the task requires retrieval of phonological representations.

EXPERIMENTS 6A AND 6B

So far, the experimental results seem to suggest that the additive and interactive relationships between polysemy and frequency are due to the types of representations used in the task-specific processes. This idea was tested further in Experiment 6. If the interactive results in the lexical decision task with degraded stimuli were because stimulus degradation induced subjects to use phonological representations, it should be possible to produce additive results even with degraded stimuli if one could prevent subjects from using phonological information to make word-nonword discriminations. This was accomplished by using pseudohomophones as the nonwords.

A pseudohomophone is a nonword that, when pronounced, sounds like a word (e.g., GRONE). Thus, these nonwords can only be discriminated from words on an orthographic basis. Previous research suggests that their use appears to induce subjects into orthographically based responding in the lexical decision task. For example, Davelaar, Coltheart, Besner, and Jonasson (1978) examined the effects of homophones (e.g., SALE / SAIL: words with two alternative spellings for a single pronunciation) on lexical decision latencies. The lexical decision latencies were slower for homophones than for nonhomophonic control words. However, the homophone effect disappeared when they replaced pronounceable nonwords (e.g., SLINT) with pseudohomophones. The argument is simply that since pseudohomophones are nonwords with identical pronunciations to actual English words, phonological information doesn't provide a clue to discriminate them from words. Therefore, the discriminations had to be made based on orthographic information. Thus, the homophone effect, which is presumably a phonologically based effect, disappeared when pseudohomophones were used as nonwords.

If the interaction between polysemy and frequency in the lexical decision task when the stimuli were degraded was due to the use of phonological information, the additive pattern of results should reappear when pronounceable nonwords are replaced by pseudohomophones. Thus, lexical decisions were examined with pseudohomophones in the clear stimulus condition (Experiment 6A) and in the degraded stimulus condition (Experiment 6B).

Method

Subjects. Fifty-five undergraduate students from the University of Western Ontario participated in these experiments for course credit. Twenty-seven subjects participated in Experiment 6A and twenty-eight participated in Experiment 6B. All were native English speakers and had normal or corrected-to-normal vision. None had participated in any of the previous experiments.

Stimuli. The word stimuli were the same as used in previous experiments, consisting of the sixty experimental word stimuli, in which word frequency and polysemy were orthogonally manipulated, and twenty filler word stimuli. However, the eighty nonwords used in these experiments were pseudohomophones. All the pseudohomophones were taken from McCann and Besner (1987) and Dennis, Besner, and Davelaar (1985). The pseudohomophones and word stimuli were matched for length. Thus, the mean pseudohomophone length was 4.45, ranging from 3 to 6. In Experiment 6A, all the stimuli and a fixation point were presented in a white color at a luminance of 12 lux (as measured from a 10 mm $\times$ 10 mm square at a 0 cm distance by a United Detector Technology, Inc., UDT-40X OPTO-METER in a darkened room). In Experiment 6B, however, the stimuli were presented at a luminance of 0.036 lux. The luminance of the fixation point was 0.10 lux.

Procedure. Subjects were tested individually. Experiment 6A was conducted in a normally lit room but Experiment 6B was conducted in a darkened room. The procedure of these experiments was identical to that in Experiments 1 and 4.

Results

The results from Experiment 6A will be reported first, followed by the results from Experiment 6B. Further, results from the combined analysis of Experiments 6A and 6B will also be reported.

Experiment 6A (clear stimulus condition)

A trial was considered an error if the lexical decision latency was less than 250 ms or more than 1500 ms. One subject showed so many errors (more than 15%) that his data were excluded from the data analyses. Thus, the data from 26 subjects were submitted to the analyses. For the 26 subjects' data, 44 data points (1.11%) were out of the allowable range mentioned above and regarded as errors. Mean lexical decision latencies for correct responses and mean error rates were calculated across subjects and items separately. The mean lexical decision latencies and error rates of the word data averaged over subjects are presented in Table 7. The mean lexical decision latency and error rate for the pseudohomophones were 733 ms and 0.08, respectively.

Subject and item means of lexical decision latencies and error rates for word data were submitted to separate analyses of variance. In the analyses of lexical decision latencies, the main effect of word frequency was significant both in the subjects' and items' analyses ($F_s(1,25)=274.22$, $p<.001$; $F_i(1,56)=28.97$, $p<.001$). The main effect of polysemy was significant in the subjects' analysis ($F_s(1,25)=9.86$, $p<.01$) although not in

Table 7
Mean Lexical Decision Latencies (in Milliseconds) and Error Rates in Experiment 6A.

	Word Frequency		
Polysemy	Low	High	RT difference
Ambiguous	652 (.036)	577 (.003)	+75
Unambiguous	670 (.100)	598 (.018)	+72
RT difference	+18	+21	

Notes - Error rates in parentheses (). Mean lexical decision latency and error rate for pseudohomophones were 733 ms and 0.08, respectively.

the items' analysis (F_i(1,56)=2.54, p>.10). The interaction between polysemy and word frequency was not significant in either analysis (F_S(1,25)=.09, p>.10; F_i(1,56)=.01, p>.10).

In the analyses of error rates, the main effect of word frequency was significant in both analyses (F_S(1,25)=16.62, p<.001; F_i(1,56)=11.73, p<.001). The main effect of polysemy was also significant in both analyses (F_S(1,25)=13.99, p<.001; F_i(1,56)=5.57, p<.025). The interaction between polysemy and word frequency was significant in the subjects' analysis (F_S(1,25)=9.35, p<.01) although not in the items' analysis (F_i(1,56)=2.09, p>.10), indicating a trend for more errors to occur for unambiguous words than for ambiguous words and this trend was larger for low frequency words.

Experiment 6B (degraded stimulus condition)

A trial was considered an error if the lexical decision latency was less than 250 ms or more than 2000 ms. Two subjects showed so many errors (more than 15%) that their data were excluded from the data analyses. Thus, the data from 26 subjects were submitted to the analyses. For the 26 subjects' data, eleven data points (0.28%) were out of the allowable range mentioned above. These were regarded as errors and excluded from the analyses of latencies. Mean lexical decision latencies for correct responses and mean error rates were calculated across subjects and items separately. The mean lexical decision latencies and error rates of the word data averaged over subjects are presented in Table 8. The mean lexical decision latency and error rate for the pseudohomophones were 825 ms and 0.07, respectively.

Subject and item means of decision latencies and error rates for word data were submitted to separate analyses of variance. In the analyses of decision latencies, the main effect of word frequency was significant both in the subjects' and items' analyses

Table 8
Mean Lexical Decision Latencies (in Milliseconds) and Error Rates in Experiment 6B.

	Word Frequency		
Polysemy	Low	High	RT difference
Ambiguous	748 (.074)	661 (.044)	+87
Unambiguous	770 (.121)	681 (.028)	+90
RT difference	+22	+20	

Notes - Error rates in parentheses (). Mean lexical decision latency and error rate for pseudohomophones were 825 ms and 0.07, respectively.

(F_S(1,25)=72.68, p<.001; F_i(1,56)=25.91, p<.001). The main effect of polysemy was significant in the subjects' analysis (F_S(1,25)=6.93, p<.025) although not in the items' analysis (F_i(1,56)=2.06, p>.10). Importantly, the interaction between polysemy and word frequency was not significant in either analysis (F_S(1,25)=.02, p>.10; F_i(1,56)=.20, p>.10).

In the analyses of error rates, the main effect of word frequency was significant in both analyses (F_S(1,25)=21.86, p<.001; F_i(1,56)=10.78, p<.01). The interaction between polysemy and word frequency was marginally significant in the subjects' analysis (F_S(1,25)=4.08, p<.06) and nonsignificant in the items' analysis (F_i(1,56)=2.70, p>.10), indicating a slight trend for more errors to occur for unambiguous words than for ambiguous words in the low frequency condition. The main effect of polysemy was nonsignificant in both analyses (F_S(1,25)=1.05, p>.10; F_i(1,56)=.67, p>.10).

Combined Analyses

The combined analyses were conducted with the data from Experiments 6A and 6B to examine the effects of stimulus quality. The 2 (word frequency) × 2 (polysemy) × 2 (stimulus quality) analyses of variance were carried out for subject and item means of lexical decision latencies and error rates separately. In the subjects' analyses, word frequency and polysemy were within-subject factors while stimulus quality was a between-subject factor. In the items' analyses, word frequency and polysemy were between-item factors while stimulus quality was a within-item factor.

In the analyses of latency data, the main effect of stimulus quality was significant in both analyses (F_S(1,50)=8.60, p<.01; F_i(1,56)=155.43, p<.001), reflecting the fact that lexical decision latencies were slower for degraded stimuli. The main effect of frequency was also significant in both analyses (F_S(1,50)=205.99, p<.001; F_i(1,56)=33.65, p<.001), reflecting the fact that lexical decision latencies were faster for high frequency words than for low frequency words. The main effect of polysemy was significant in the subjects' analysis ($Fs(1,50)=16.03$, $p<.001$) and marginally significant in the items' analysis ($F_i(1,56)=2.80$, $p<.10$), suggesting that lexical decision latencies were faster for ambiguous words than for unambiguous words. However, none of the interactions were significant in either analysis (all $Fs<1.9$).

In the analyses of error rates, the main effect of stimulus quality was significant in both analyses ($F_s(1,50)=6.31$, $p<.025$; $F_i(1,56)=15.47$, $p<.001$). The main effect of frequency was significant in both analyses ($F_s(1,50)=38.07$, $p<.001$; $F_i(1,56)=13.24$, $p<.001$). The main effect of polysemy was significant in the subjects' analysis ($F_s(1,50)=8.96$, $p<.01$) and marginally significant in the items' analysis ($F_i(1,56)=2.83$, $p<.10$). The two-way interaction between polysemy and frequency was significant in the subjects' analysis ($F_s(1,50)=10.28$, $p<.01$) and marginally significant in the items' analysis ($F_i(1,56)=2.83$, $p<.10$). The two-way interaction between polysemy and stimulus quality was marginally significant in the items' analysis ($F_i(1,56)=3.02$, $p<.09$) but not in the subjects' analysis ($F_s(1,50)=1.75$, $p>.10$). All other effects were nonsignificant (all $Fs<1$).

Discussion

The results from both experiments were quite similar to those in Experiment 1. Polysemy was additive with frequency on lexical decision latencies regardless of stimulus quality but interactive on error rates. As in Experiment 1, when the two word pairs (*hail - veto*, & *spade - sewer*) were excluded, this interaction of error rates again disappeared in both Experiments 6A ($F_s(1,25)=2.06$; $F_i(1,52)=.87$, $ps>.10$) and 6B ($F_s(1,25)=1.58$; $F_i(1,52)=1.27$, $ps>.10$).

These results support the conclusion that the interaction between polysemy and frequency which appeared in Experiment 4 was because stimulus degradation biased subjects to discriminate words from nonwords using phonological information. That is, since the availability of orthographic information was poor with degraded stimuli, subjects seemed to retrieve and use phonological representations of the stimuli. Thus, lexical decisions were phonologically based. Therefore, similar to the results in naming tasks, polysemy interacted with frequency. However, in the present experiments, subjects were required to make lexical decisions based on orthographic information because phonological information could provide no clue to discriminate words from pseudohomophones. Thus, as in Experiment 1, the additive relationship between polysemy and frequency appeared regardless of stimulus quality. Therefore, it seems possible to conclude that polysemy effects occurred for both high and low frequency words when the task required orthographically based processes whereas the effects were limited to low frequency words when the task required phonologically based processes.

Neither the two-way interaction between frequency and stimulus quality nor the three-way interaction between polysemy, frequency, and stimulus quality were significant in the combined analyses. Thus, the size of frequency effects didn't change depending on the stimulus quality. Contrary to the results from the combined analysis between Experiment 1 and Experiment 4, the present results support the theoretical independence of frequency and stimulus quality. These results seem to suggest that when orthographically based lexical decisions are carried out (regardless of stimulus quality), frequency effects are independent of the stimulus quality. When stimulus degradation induces subjects to make phonologically based lexical decisions, however, frequency effects are not necessarily independent of the stimulus quality. Since the representations used to make lexical decisions differed depending on stimulus quality, the nature of the decision making processes giving rise to frequency effects in the two conditions differed as well. Thus, this difference seems to produce the different patterns of frequency effects depending on the stimulus quality. Note also that the results from the combined analyses between Experiment 2 and Experiment 5 showed the interaction between frequency and stimulus quality on naming latencies. These facts may further suggest the possibility that frequency interacts with stimulus quality when the task requires the retrieval of phonological representations regardless of stimulus quality. Although these are only tentative conclusions, they are worth examining further to understand the relationship between frequency, stimulus quality, and the type of representations used during the task-specific processes.

GENERAL DISCUSSION

The main purpose of the present studies was to examine whether semantic variables such as polysemy have any effects on the speed of lexical access. As in Balota and Chumbley (1984, 1985), two word recognition tasks (lexical decision and naming) were assumed to consist of a common lexical access process and the postaccess, task-specific processes. Thus, if there are observable effects common to different tasks, those effects should be considered to be due to the common lexical access process. Although the effects of polysemy and frequency appeared in both lexical decision and naming tasks, the patterns of results were different. Polysemy was additive with frequency on lexical decision latencies but interacted with frequency on naming latencies.

Balota and Chumbley (1984) claimed that naming latencies are better measures of lexical access than lexical decision latencies. They argued that since the lexical decision task requires word-nonword decisions, lexical decision latencies are contaminated by postaccess decision making components. The naming task, however, does not require word-nonword decisions. Therefore, the postaccess, task-specific effects should be minimal for naming latencies and naming latencies should be more sensitive to effects occurring during lexical access. Based on Balota and Chumbley's claim, one possible explanation for the differential effects of polysemy was that polysemy affected lexical access as observed for naming latencies, but the pattern changed during the decision making processes in the lexical decision task.

Another possibility, however, was to consider that the differential patterns were each due to the task-specific components. That is, the interaction between polysemy and frequency may occur at the postaccess processes specific to the naming task and the additive relationship between these variables may be due to the postaccess processes specific to the lexical decision task. Given these alternative explanations of the differential results in lexical decision and naming, these alternatives were examined in the go-no go naming task. The former explanation suggested that there should be no difference in the results between the lexical decision task and the go-no go naming task because these tasks are identical except for the modality of responses. However, the latter explanation suggested that there should be an interaction between polysemy and frequency on go-no go naming latencies. Since the go-no go naming task is assumed to consist of lexical access, the decision making processes, and the pronunciation-related processes, the decision making processes, as in the lexical decision task, may produce polysemy effects which are additive with frequency. Further, the pronunciation-related processes, as in the naming task, may produce polysemy effects which are interactive with frequency. Therefore, the polysemy effects should appear for both high and low frequency words but the size of the effects should be larger for low frequency words.

The results from the go-no go naming task confirmed this latter prediction. The effects of polysemy were approximately equal to the sums of the effects in lexical decision and in naming (41 ms ÷ 18 ms + 20 ms for low frequency words; 18 ms ÷ 13 ms + 1 ms for high frequency words). Further, the frequency effects showed quite similar patterns. Frequency effects on go-no go naming latencies were also approximately equal to the sums of the frequency effects in lexical decision and in naming (84 ms ÷ 65 ms + 12 ms for ambiguous words; 107 ms ÷ 70 ms + 31 ms for unambiguous words). If some portions of these effects were due to lexical access, the sum of the effects on lexical decision latencies and on naming latencies should be larger than the effects on go-no go naming latencies because summing these effects should involve adding the lexical access component twice. (It seems unlikely that lexical access occurred twice in the go-no go naming task.) However, as noted, the sizes of frequency and polysemy effects on go-no go naming latencies were approximately equal to the sums of the effects on lexical decision latencies and those on naming latencies. Therefore, these results seem to suggest that the effects of frequency as well as polysemy were only minimal during lexical access Rather, these variables seem to affect postaccess processes specific to each task.

Most of the previously proposed accounts of polysemy effects have suggested that polysemy affects the lexical access process. Rubenstein et al. (1970, 1971) and Jastrzembski (1981) explained polysemy effects by assuming different numbers of lexical entries for ambiguous and unambiguous words. That is, because ambiguous words have more entries, the probability of accessing one of these entries should be greater. Thus, ambiguous words are considered to be accessed faster than unambiguous words. Balota, et al. (1991) suggested another lexical access account of polysemy effects in the framework of the interactive-activation model. They explained the polysemy effect as due to feedback activation from the meaning level units to the word level units Contrary to these lexical access accounts, however, the present results indicated that there is little influence of polysemy during lexical access, rather, polysemy effects are due to the postaccess processes specific to each task.

Word frequency effects have also been explained by assuming frequency sensitive lexical representations as in logogen-type models (e.g., Morton, 1969; McClelland & Rumelhart, 1981) or by assuming frequency ordered matching processes to access lexical representations as in the verification model (Becker, 1980) or the lexical search model (Forster, 1976). These models assume that frequency effects arise during lexical access Some researchers, however, have recently argued for the possibility of postaccess loci for frequency effects. Balota and Chumbley (1984) argued that frequency effects on lexical decision latencies were mostly due to the decision making processes Balota and Chumbley (1985) also argued that a part of the frequency effects for naming latencies was due to the production processes Further, McCann and Besner (1987) suggested that frequency effects on naming latencies may arise not because representations themselves are frequency-sensitive but because the connections between orthographic and phonological representations are frequency sensitive. The PDP models' (e.g., Seidenberg and McClelland, 1989; Brown, 1990) accounts of frequency effects were quite similar to McCann and Besner's account. In these models, frequency effects arise based on the computation from the orthographic input to phonological output because the weights on connections between orthographic input units and phonological output units (via hidden units) are determined based on the frequency of experience with the words during a training phase. Thus, the present results concerning the effects of frequency seem to be most consistent with these postaccess accounts.

Given the conclusion that both polysemy and frequency affect postaccess processes specific to each task, the next issue to consider was what are the differences between these postaccess, task-specific processes and how could they explain the different types of relationships between polysemy and frequency. Seidenberg and his colleagues (Seidenberg, 1985; Seidenberg, 1989; Waters & Seidenberg, 1985; Seidenberg & McClelland, 1989) have described the difference between lexical decision and naming in terms of the types of representations used to accomplish each task. They have argued that naming explicitly requires access to phonological representations because this task requires correct pronunciations of words. On the other hand, the lexical decision task doesn't necessarily require access to phonological representations because the word-nonword discriminations are often possible based merely on orthographic information. If this is the case, the interactive relationship between polysemy and frequency which was observed in the naming task and the additive relationship between these variables which was observed in the lexical decision task may be because of the types of representations used during the task-specific processes. Thus, to examine whether the types of representations used are responsible for the differential patterns of results, lexical decision and naming tasks were examined using degraded stimuli. Seidenberg and his colleagues argued that although subjects often make lexical decisions based on orthographic information, when the orthographic information doesn't provide enough of a clue to discriminate words from nonwords, subjects change their decision strategy to use phonological information (Waters & Seidenberg, 1985). Since word stimuli seem to be more nonword-like when they are degraded, the orthographic familiarity difference between words and nonwords should decrease and word-nonword discriminations should be more difficult on the basis of the orthographic familiarity. Therefore, it seemed likely that stimulus degradation could also bias subjects to use phonological information as the basis for discriminating words from nonwords. Thus, if the interaction between polysemy and frequency was due to the use of phonological representations during the postaccess, task-specific processes, the interaction should appear not only on naming latencies but also for lexical decision latencies when the stimuli are degraded. This hypothesis was confirmed. When the stimuli were degraded, the interaction between polysemy and frequency appeared not only in naming but also in lexical decision.

The interactive results from the lexical decision task also suggest that the observed interaction should not be attributed to production processes, because the lexical decision task doesn't require production of overt pronunciations. Rather, this interaction seems to arise during the process of retrieving phonology. Thus, the frequency effects as well as the polysemy effects on naming latencies seems also to be due to the processes of retrieving phonological representations.

In a final examination of the issue regarding the types of representations, the pronounceable nonwords were replaced by pseudohomophones in lexical decision tasks This manipulation should discourage the use of phonology because these nonwords sound like actual English words. In these experiments, the additive relationship between polysemy and frequency reappeared regardless of stimulus quality, supporting the claim that this additive relationship is due to the use of orthographic information.

Since the additive relationship between polysemy and frequency was observed in both stimulus quality conditions when the pronounceable nonwords were replaced by pseudohomophones, these results suggest that subjects could still use orthographic information as the basis for the word-nonword decisions even when the stimuli were degraded. Nonetheless, when pronounceable nonwords were used, subjects seem to make phonologically based decisions for degraded stimuli. Thus, the use of orthographic or phonological information as the basis for the decisions seems to be under subjects' strategic control. Further, when the availability of orthographic information was limited, subjects seem to prefer to use phonological information because it provides a more stable basis for making responses. For example, Brown (1991) asked subjects to respond to the direction of an arrow which was presented on a screen preceded by a masked prime stimulus. The lexical status of the masked prime stimuli corresponded to the arrow's directions. That is, a word prime always followed a right-faced arrow, while a nonword prime followed a left-faced arrow. The nonword primes consisted of pronounceable nonwords and pseudohomophones. The reaction times for the arrow's responses were compared between these types of nonwords to examine whether phonological information is available when the subjects make their responses. The results showed that the reaction times were slower for pseudohomophones than for pronounceable nonwords when the stimulus onset asynchronies (SOAs) between the prime and the mask was shorter (up to 250 ms). Such difference in reaction times, however, disappeared when the SOA became longer (450 ms) These results seem to suggest that when the availability of orthographic information was limited due to masking, orthographic information didn't provide a stable basis for making responses. Rather, subjects seem to use phonological information. When the SOA was long enough, however, the availability of more stable orthographic information provided a better basis for making a response. Thus, subjects seem to change their response strategy to use orthographic information as the basis for responding.

Further, Van Orden (1987) examined the effect of homophone foils in category-verification experiments. A category name (e.g., FLOWER) was presented followed by a target letter string. Subjects were asked to decide whether the target was an exemplar of the given category. The target stimulus set included homophone foils (e.g., ROWS) and their spelling control foils (e.g., ROBS). The orthographic similarity of these foils to their corresponding category exemplar (e.g., ROSE) was manipulated. When the target was presented for 500 ms followed by a pattern-mask, false positive errors on homophone foils (18.5%) were greater than those for their spelling control foils (3%). In addition, the false positive errors on homophone foils were greater for similarly spelled homophone foils (29%) than for less similarly spelled homophone foils (8%). In the next experiment, the target exposure duration was shortened. The false positive errors for homophone foils (43%) were again greater than those for their spelling control foils (17.5%) and, importantly, the effect of orthographic similarity on homophone foils disappeared. The false positive errors were 40% for similarly spelled homophone foils and 46% for less similarly spelled homophone foils. These results also seem to indicate a tendency for subjects to rely more on phonological information when the availability of orthographic information was limited. Since phonological representations are considered more suitable for retention, under the conditions in which the availability of orthographic information is limited, it seems reasonable to argue that subjects use a phonologically based strategy for making responses because phonological representations seem to provide a more stable basis for allowing cognitive processes to operate to effectively.

This argument seems to be applicable not only to masking conditions but also to the stimulus degradation Thus, when the availability of orthographic information was limited due to the degradation, subjects seem to prefer to use phonological information as the basis for making responses because phonological information provides a more stable basis for responding than the degraded (and, therefore, unstable) orthographic information.

The entire pattern of data is summarized in Table 9. The interaction between polysemy and frequency was observed in the naming task with clear stimuli, the naming task with degraded stimuli, and the lexical decision task with degraded stimuli. On the other hand, an additive relationship between these variables appeared in the lexical decision task with clear stimuli and the lexical decision tasks using pseudohomophones as nonwords. Thus, two differential patterns of results appeared in identical tasks (lexical decision) and identical results were obtained in different tasks (lexical decision and naming), indicating that the differential patterns of polysemy effects were independent of task type. Therefore, the pattern of results does not appear to be due to the type of operations carried out during the task-specific processes, but rather due to the type of representations used during the task-specific processes.

Based on these results, it seems difficult to assume dictionary-like representations in which all the information for each word is stored in the same location, as assumed by early models of the lexicon. For example, Forster's (1976) model consists of peripheral access files and a master file. The peripheral file consists of a list of access codes and

Table 9
Summary of the Results from Lexical Decision (LDT) and Naming (NM) Tasks.

No.	Task	Stimulus Quality	Nonwords	Representations	Experimental Results (Polysemy & Frequency)
1	LDT	Clear	Pronounceable	Orthographic	Additive
2	NM	Clear	————	Phonological	Interactive
4	LDT	Degraded	Pronounceable	Phonological	Interactive
5	NM	Degraded	————	Phonological	Interactive
6A	LDT	Clear	Pseudohomophone	Orthographic	Additive
6B	LDT	Degraded	Pseudohomophone	Orthographic	Additive

Notes - Six experiments were described in terms of task type, stimulus quality, nonword type, and the type of representations which seem to play a key role to producing responses. The pattern of relationship between polysemy and frequency corresponded to the types of representations used to accomplish the tasks.

pointers which correspond to entries in the master file. Each entry in the master file contains all the information we have acquired for a particular word. Thus, orthographic, phonological, and semantic information were all assumed to be located in the same entry in the master file. This model describes the lexical access as the process of accessing a correct entry in the master file when a visual input is presented. In such a framework, all the information should be available at the same time as soon as lexical access is accomplished. Thus, there would be no reason to expect differential relationships between polysemy and frequency depending on the type of representations used during the postaccess processes as observed in the present experiments. Rubenstein and his colleagues (1970, 1971) and Jastrzembski (1981) further assumed that there were multiple entries for ambiguous words with each entry representing one meaning. This extra assumption seems not to provide any better account of the present results because the assumption leads to the prediction that polysemy effects should occur during lexical access and, thus, the effects should be identical regardless of task type. Rather, the differential patterns of results seem to reflect the difference in availability of orthographic, phonological, and semantic information during the postaccess processes in each task. Thus, it seems more reasonable to assume separate representations for orthographic, phonological, and semantic information for words.

The discussion of the present results has been within the framework of the common assumption that the lexical access process is an initial input process which is common to a variety of word recognition tasks (e.g., Balota & Chumbley, 1984; Balota & Chumbley, 1985; Chumbley & Balota, 1984). This assumption seems to be necessary and reasonable because, as suggested by Fodor (1983), the visual inputs have to be initially mapped to the representation system for cognitive processes to further operate on that information. Thus, lexical access was defined as the input process that maps physical inputs to lexical representations. The present results, however, suggest that neither the polysemy effect nor the frequency effect appear to be due to this initial input process. Rather, those effects seem to be due to the task-specific processes which are carried out after the initial input process. Recently, Seidenberg and McClelland (1989) and Seidenberg (1989) have questioned and abandoned the notions of "lexical access" and "lexicon." The present data do not provide any good argument against the Seidenberg and McClelland position since the "lexical access" process appeared to play essentially no role in producing the effects in the present studies. Thus, although many researchers have argued for the importance of "lexical access" in word recognition, the role of the "lexical access" process in word recognition may have been overestimated.

Since the two different relationships between polysemy and frequency appear to be due to the type of representations used during the task-specific processes, the present results seem to suggest that there are two different ways in which semantic representations are accessed. Since the additive relationship between polysemy and frequency was due to the use of orthographic representations, the additive results presumably reflect the nature of orthographically based direct access to semantic representations. Similarly, the interactive results due to the use of phonological representations presumably reflect the nature of phonologically mediated access to semantic representations.

A number of researchers have addressed the issue of the nature of information used to access word meanings. They have focused their attention on whether accessing meanings is accomplished directly from orthography or mediated by phonology. Carr and Pollatsek (1985) classified word recognition models into two types in terms of the nature of codes or representations used to access meanings. The first type was models in which access to meanings was assumed to be accomplished directly from orthography such as the logogen model (Morton, 1969), the verification model (Becker, 1980), and the lexical search model (Forster, 1976). The second type of model, on the other hand, assumed two parallel routes to access meanings such as in the dual-route model (Coltheart, 1978) and the time-course model (Seidenberg, 1985). That is, an orthographically based direct access route and a phonologically mediated access route were assumed in these models. Carr and Pollatsek denied the possibility of assuming a single phonologically mediated access route because it seems necessary to assume an orthographically based access for the recognition of homophones. Van Orden and his colleagues (e.g., Van Orden, Johnston, & Hale, 1988; Van Orden, Pennington, & Stone, 1990), however, have recently argued for a model of this type.

Van Orden, et al. (1988) examined the effects of homophones and pseudohomophones in the category verification experiments. Subjects were asked to decide whether the target was an exemplar of the given category (e.g., A PART OF THE HUMAN BODY). The target stimuli included homophone foils (e.g., HARE), pseudohomophone foils (e.g., BRANE), and their respective spelling control foils. Their primary interest was to examine false positive error rates for these types of foils. If meanings were accessed only directly from orthographic representations, there should be no difference in false positive error rates between homophonic foils and their spelling control foils. Further, if there are two independent access routes to meaning, false positive error rates for homophone foils should be smaller than those for pseudohomophone foils because meanings of homophones can be accessed through the direct access route. The results showed that false positive error rates for homophonic foils were greater than those for spelling control foils. In addition, there was no difference in false positive error rates between homophone foils and pseudohomophone foils. Based on these results, Van Orden, et al. argued that semantic access is always mediated by phonological representations.

In Van Orden, et al.'s experiments, however, false positive error rates for homophonic foils were about twenty to thirty per cent. Thus, subjects responded correctly in about seventy to eighty per cent of homophonic foil trials. It seems unclear whether the single mediated access account can explain this fact. Since the target was primed by the category name, false positive error rates for homophonic foils should be quite large if the phonological representations were the only source of access to meaning. Therefore, although their results clearly suggested the existence of a phonologically mediated access route to meaning, it seems a bit difficult to explain the high rate of correct responding.

Contrary to Van Orden's claims, the results in the present studies suggested that there are two independent access routes to meanings. When the task-specific processes used orthographic representations to complete the task, polysemy was additive with frequency. When the processes used phonological representations, polysemy interacted with frequency. Since polysemy effects can be taken as evidence of semantic access, the two differential patterns of results seem to suggest that there are two independent access routes to semantic representations. In other words, it seems necessary to assume two independent access routes to semantic representations to explain the present results.

Seidenberg and McClelland (1989) proposed a PDP model in which separate orthographic, phonological, and semantic levels were assumed, each having distributed representations. Although the semantic units are not yet implemented in their model, they assume that the orthographic, phonological, and semantic units are connected to each other through hidden units. Thus, the model assumes two independent computations to access word meanings. That is, the activation of semantic units is computed from the activation of orthographic units or from the activation of phonological units. Given such architecture, they further argue for the possibility of cascading processes or interactive activation between orthographic and semantic units and between phonological and semantic units. Thus, this model seems to have the potential to explain the results from the present studies. When orthographically based processing is required (e.g., a lexical decision task with pseudohomophones), meaning access occurs from orthography to semantics and the semantic activation, then, influences the orthographically based processing. Similarly, when a task requires phonologically based processing (e.g., a naming task), meanings are accessed from phonology and the semantic activation, in turn, influences the phonologically based processing. Thus, the fact that there are different relationships between polysemy and frequency could be explained based on the different computational routes to semantic units.

Similarly, this cascading process is assumed by Fera, et al. (1993) to explain the polysemy effect in the naming task. Fera, et al. assumed that the summation of activation at the phonological level is greater for ambiguous words because the activation of multiple semantic representations converge on a single phonological representation. Thus, they argue that the computation of phonological representations becomes faster for ambiguous words than for unambiguous words. Although this account was limited to phonological computations, it seems possible to apply the same account to orthographic computations by assuming such a cascading process between orthographic and semantic representations. For example, in Seidenberg and McClelland's (1989) network, orthographic output units were assumed in addition to the orthographic input units. Thus, the computations to produce orthographic output activation as well as those to produce phonological output activation seem to be faster for ambiguous words because multiple semantic representations should converge not only on a single phonological representation but also on a single orthographic representation. Thus, by assuming different cascading processes between phonological and semantic representations and between orthographic and semantic representations, the polysemy effects in the present studies could be explained in the framework of PDP network.

Assuming the two essentially independent interactive (bi-directional) routes to semantic representations, the crucial question is why we observed the particular relationships between polysemy and frequency reported here. That is, why was the pattern interactive when semantic access was mediated by phonological representations and additive when the semantic representations were accessed directly from orthographic representations?

Based on additive factors' logic (Sternberg, 1969), the additive relationship between two variables is assumed to indicate that these variables affect separate stages independently, whereas the interactive relationship is assumed to indicate that these variables affect a common stage. According to this logic, polysemy and frequency are considered to affect separate stages in the lexical decision task but are considered to affect a common stage in the naming task. Since the results from the lexical decision, naming, and go-no go naming tasks suggested that both polysemy and frequency affect the decision making processes in the lexical decision task and the pronunciation-related process in the naming task, the additive relationship between polysemy and frequency on lexical decision latencies may suggest that the decision making processes consist of two separate processing stages. As Sternberg was careful to point out, however, two factors could affect a common stage in an additive fashion. Thus, the existence of additive effects should only be regarded as evidence for separate stages if the separate stage assumption makes sense in the larger context. In the present instance, the suggestion is that it is more parsimonious to argue that polysemy and frequency affect the same postaccess stage but in an additive fashion.

Seidenberg and McClelland's (1989) model actually provides an example of how two factors can affect the same stage in an additive fashion. In the model, the effects of regularity and frequency were presumed to occur based on the weights on connections between orthographic input units and phonological output units. Both of these effects would arise during the same processing stage and, thus, this model could simulate the standard interaction between spelling-sound regularity and frequency in the naming task (e.g., Andrews, 1982; Seidenberg, et al., 1984; Waters & Seidenberg, 1985). In the model, however, the weights on connections between orthographic input units, hidden units, and phonological output units must be adjusted during the training phase and these weights, then, depend upon the amount of experience with the words themselves and with words which share similar spelling-sound correspondences. What is most relevant is that early in training in their simulation of the regularity effect, the effect appeared not only for low frequency words but also for high frequency words. That is, an additive relationship between regularity and frequency was observed. Only with additional training was the regularity effect for high frequency words reduced and the interactive relationship between regularity and frequency was observed. What is occurring is that because high frequency words are experienced so frequently, the correspondences between spelling and sound for these words become overlearned and strong connections between a particular spelling and a particular sound are established regardless of regularity. Thus, the output for both regular and exception words approached asymptote and the regularity had no effects on the computations from orthographic inputs to phonological outputs for high frequency words. For low frequency words, however, the correspondences from a particular spelling to a particular sound for these words were less well learned because of less frequent experience with these words. Thus, for low frequency words, the connections between a particular spelling and a particular sound were relatively weak. Because of such weak connections, the computations from orthographic inputs to phonological outputs were affected by the correspondences between similar spelling and similar sound which were shared by many other similarly spelled words. Thus, the effects of regularity appeared for low frequency words.

The important point to be made here is that applying the same computation from orthographic input to phonological output, Seidenberg and McClelland's model could produce both the additive and the interactive relationship between regularity and frequency. This simulation clearly indicates that it is possible for two variables to produce an additive effect even when they affect a common stage. As such, the additive relationship between polysemy and frequency which was observed in the lexical decision task does not necessarily imply that polysemy and frequency affect separate stages. Rather, as suggested by the Seidenberg and McClelland's model, the differential relationships between polysemy and frequency may reflect that there is a difference in the strength of correspondences between representations. That is, in their model, the additive relationship between regularity and frequency was observed in early training phase, whereas the interaction appeared only with additional training. Thus, the additive and the interactive relationship between two variables may imply the different strengths of correspondences between two representations, which reflects the frequency of experience. Since, in the present studies, the additive relationship between polysemy and frequency appeared when orthographic representations were used, the additive relationship may imply that the connections between orthographic and semantic representations are relatively weak and may not be experienced frequently. On the other hand, the interactive relationship between polysemy and frequency was observed when phonological representations were used. Thus, the interaction may suggest that the connections between phonological and semantic representations for high frequency words are quite strong and the semantic representations may have been accessed more frequently through the phonologically mediated route than through the orthographically based route.

This suggestion receives some support in the previous literature. Doctor and Coltheart (1980), for example, examined a sentence verification task for children aged from 6 to 10. Some of the sentences contained a homophone or a pseudohomophone. These sentences were nonsensical but sounded meaningful (e.g., "He ran threw the street"). Their results showed that the correct rejections for these sentences increased as a function of the age of subjects. Thus, the results indicated that beginning readers rely more on phonologically mediated semantic access. The results also seem to suggest that the correspondences between phonology and meanings are learned earlier than the correspondences between orthography and meanings. In addition, we may receive words in conversation more often than in reading text in our daily experience. If so, we may have more opportunities to learn the correspondences between phonological and semantic representations than the correspondences between orthographic and semantic representations. Thus, these considerations seem to provide a plausible account of the differential patterns of results obtained in the present studies by focusing on the difference in strength of correspondences between phonology and semantics and between orthography and semantics

Through the examinations of the effects of polysemy and frequency on lexical decision latencies and on naming latencies, two differential patterns of results appeared and the difference appeared to be due to the type of representations used during the task-specific processes. Since polysemy is a semantic variable, polysemy effects are assumed to be evidence of semantic access. Thus, two differential patterns of results for the relationships between polysemy and frequency were considered to indicate that there are two different access routes to semantic representations. When meanings were accessed as a result of using orthographic representations, an additive relationship between polysemy and frequency appeared. On the other hand, when meanings were accessed as a result of using phonological representations, an interactive pattern was observed. Based on the PDP framework, the additive and the interactive relationships between polysemy and frequency were considered to reflect the difference in strength of correspondences between orthographic and semantic representations and between phonological and semantic representations which have been established through the daily experience of reading and hearing.

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APPENDIX

Ambiguous-Unambiguous Word Pairs Used in Experiments

Low Frequency	
Ambiguous	Unambiguous
perch	evade
rash	fern
punch	badge
hail	veto
spade	sewer
shed	wool
limp	cult
drag	lung
seal	lamp
lean	tent
pupil	solve
beam	mode
bowl	gang
sink	pond
draft	beard

High Frequency	
Ambiguous	Unambiguous
watch	event
post	nine
pass	lady
base	loss
date	news
mass	lack
shot	clay
march	green
club	paid
range	river
fine	food
miss	half
order	often
right	small
well	also