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Semantic Ambiguity and the Process of Generating Meaning From Print

Penny M. Pexman
University of Calgary

Yasushi Hino
Chukyo University

Stephen J. Lupker
The University of Western Ontario

An ambiguity disadvantage (slower responses for ambiguous words, e.g., *bank*, than for unambiguous words) has been reported in semantic tasks (L. R. Gottlob, S. D. Goldinger, G. O. Stone, & G. C. Van Orden, 1999; Y. Hino, S. J. Lupker, & P. M. Pexman, 2002; C. D. Piercey & S. Joordens, 2000) and has been attributed to the meaning activation process. The authors tested an alternative explanation: The ambiguity disadvantage arises from the decision-making process in semantic tasks. The authors examined effects of ambiguity on unrelated trials in a relatedness decision task, because these trials are free from response competition created by ambiguous words on related trials. Results showed no ambiguity effect on unrelated trials (Experiments 2, 3c, and 5c) and an ambiguity disadvantage on related trials (Experiments 3a, 3b, 5a, and 5b).

One of the many ambiguities inherent in the English language is created by the fact that most words have more than one meaning (e.g., *bank*). The processes by which word meanings are activated, and any potential meaning ambiguities are resolved, are central concerns in psycholinguistic research. These issues are also the focus of the present article.

Semantic Ambiguity Effects

Parallel distributed processing (PDP) models have become popular descriptions of the word recognition process (e.g., Plaut, McClelland, Seidenberg, & Patterson, 1996; Seidenberg & McClelland, 1989). As demonstrated by Joordens and Besner (1994; see also Besner & Joordens, 1995; Borowsky & Masson, 1996; Kawamoto, Ferrar, & Kello, 1994; Rueckl, 1995), however, those models have considerable difficulty capturing the nature of semantic ambiguity effects, specifically, the fact that there is typically an ambiguity advantage in lexical decision tasks (LDTs). That is, response times (RTs) in LDTs are usually faster for ambiguous than for unambiguous words (Borowsky & Masson, 1996; Hino & Lupker, 1996; Jastrzembski, 1981; Jastrzembski & Stanners, 1975; Kellas, Ferraro, & Simpson, 1988; Millis & Button, 1989; Pexman & Lupker, 1999; Rubenstein, Garfield, & Millikan, 1970).

PDP models involve separate sets of orthographic, phonological, and semantic units. These units are distributed and interconnected, and connections between sets of units are weighted to reflect learned correspondences between, for instance, spelling (orthography) and meaning (semantics). The problem for the PDP models is that, if anything, they predict an ambiguity disadvantage in LDTs. Specifically, due to the fact that ambiguous words involve one-to-many mappings between orthography and semantics, these words should have difficulty settling into stable patterns of semantic activation. Indeed, Joordens and Besner's (1994) simulations involving Seidenberg and McClelland's (1989) model, Hinton and Shallice's (1991) model, and Masson's (1991) model showed that all the models produce longer settling times for words with one-to-many mappings (ambiguous words) than for words with one-to-one mappings (unambiguous words). If accurate performance in the LDTs requires settling in the semantic units, as Joordens and Besner assumed, then the prediction of PDP models is that responses should be delayed for ambiguous words relative to unambiguous words. This is, of course, exactly opposite to the pattern actually observed in LDT experiments. Two main solutions to this problem have been offered, both couched within the PDP framework: accounts that localize the effect outside the semantic system (e.g., in the orthographic system as in our feedback account; Hino, Lupker, & Pexman, 2002), and the efficient-then-inefficient processing explanation of Joordens and colleagues (e.g., Piercey & Joordens, 2000).

The Feedback Account

In Seidenberg and McClelland's (1989) original PDP model, connections between sets of units were assumed to be bidirectional. Thus, it was proposed that the process of recognizing

Penny M. Pexman, Department of Psychology, University of Calgary, Calgary, Alberta, Canada; Yasushi Hino, Department of Psychology, Chukyo University, Nagoya, Japan; Stephen J. Lupker, Department of Psychology, The University of Western Ontario, London, Ontario, Canada.

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Correspondence concerning this article should be addressed to Penny M. Pexman, Department of Psychology, University of Calgary, 2500 University Drive Northwest, Calgary, Alberta, T2N 1N4 Canada. E-mail: pexman@ucalgary.ca

printed words would involve, first, orthographic activation, and then *feedforward* activation from orthography to phonology and from orthography to semantics. There would also be *feedback* activation from phonology to orthography and from semantics to orthography, as processing continued. Seidenberg and McClelland did not implement these feedback connections, but they were included in some of Plaut and Shallice's (1993) simulations. Similarly, Van Orden and Goldinger (1994; see also Gottlob, Goldinger, Stone, & Van Orden, 1999; Stone, Vanhoy, & Van Orden, 1997) argued for a system that incorporated both feedforward and feedback activation between sets of units.

As argued by Hino and Lupker (1996), a generic PDP framework that incorporates the assumption of bidirectional activation flow does offer an explanation of the ambiguity advantage in LDTs. Building on ideas proposed by Balota, Ferraro, and Connor (1991), Hino and Lupker proposed the following: For all words, there is initially activation of an orthographic representation, followed rapidly by semantic activation (and presumably also phonological activation, however, our focus here is on the connections between orthography and semantics). Because ambiguous words, by definition, have multiple meanings, they typically activate more semantic units than unambiguous words do. Because activated semantic units provide feedback activation to the orthographic units, the feedback activation would, therefore, be stronger for ambiguous words than for unambiguous words. The consequence should be more rapid activation of the orthographic units for ambiguous words. Hino and Lupker also assumed that LDT performance is based primarily on activation of the orthographic units. That is, attention is directed to the orthographic units and away from semantic and phonological units (see also Balota, Paul, & Spieler, 1999), although semantic and phonological activation certainly have an influence on LDT performance via feedback connections to orthography. As such, responding should be faster in LDTs for ambiguous words than for unambiguous words, as has typically been observed.

The Efficient-Then-Inefficient Explanation

A different account of the ambiguity advantage in LDTs was offered by Joordens and colleagues (Besner & Joordens, 1995; Joordens & Besner, 1994; Piercey & Joordens, 2000). Their proposal was that ambiguous words produce a "blend" state in the semantic units, which is a pattern of activation that represents multiple learned meanings. Furthermore, LDT performance is assumed to involve a similarity assessment, comparing the activated semantic representations to patterns in memory. Critically, this assessment can be made prior to completed (fully settled) semantic processing, in fact, as soon as semantic activation has reached a threshold level. Thus, the blend can be a sufficient basis for responding in LDTs. As ambiguous words are presumed to reach a threshold level of semantic activation earlier than unambiguous words, the expected result is an ambiguity advantage in LDTs. In contrast to the feedback account, Joordens and colleagues did not propose that orthographic activity was emphasized in LDTs, instead they assumed that semantic activity provided the basis for LDT performance.

Predicted Effects of Ambiguity in Semantically Based Tasks

The basic premise of the efficient-then-inefficient explanation is that, although a blend state might be sufficient for LDT performance, it would be insufficient in tasks requiring more complete semantic processing (Piercey & Joordens, 2000). Thus, Piercey and Joordens claimed that ambiguous words should produce a processing advantage in LDTs, but they would produce a processing disadvantage in semantically based tasks because the semantic system would have difficulty escaping the blend state. Supporting this view, Piercey and Joordens reported an ambiguity advantage in LDTs and an ambiguity disadvantage in a relatedness decision task (i.e., "Are these two words related?"). They concluded that "this is because lexical decisions can be made relatively early in processing, where ambiguous words have an advantage. Relatedness judgments require a specific meaning for an ambiguous word, which is not obtained until the item has been processed more deeply (i.e., a blend state is not sufficient to support a relatedness judgment)" (Piercey & Joordens, 2000, p. 664).

The feedback account would make the same predictions as the efficient-then-inefficient explanation for performance in LDTs and in the relatedness decision task, albeit for different reasons. According to the feedback account, LDT performance is influenced by the nature of feedback connections from semantics to orthography, whereas performance in semantically based tasks (e.g., relatedness decisions) is influenced by the nature of feedforward connections from orthography to semantics. Orthographic activation is emphasized in LDTs, but semantic activation is emphasized in semantic tasks such as relatedness decisions. As a result, one-to-many mappings between orthography and semantics for ambiguous words should produce an ambiguity disadvantage in a semantically based task. This prediction was confirmed by Hino et al. (2002): Results showed an ambiguity advantage in LDTs and, with the same stimuli, an ambiguity disadvantage in a semantic categorization task (i.e., "Is it a living thing?"). Similarly, Gottlob et al. (1999) reported an ambiguity disadvantage in their relatedness decision task. These results suggest that the semantic coding process (which is presumed to be the basis for responding in semantically based tasks) is slowed by one-to-many feedforward connections between orthography and semantics. In particular, Gottlob et al. argued that for ambiguous words there is competition between meanings that must be resolved before a response can be made in a semantically based task.

Both the efficient-then-inefficient explanation and the feedback account could, therefore, explain any ambiguity disadvantage as being due to the way that semantic coding is accomplished. In contrast, Forster (1999) reported results that appear to be problematic for both accounts. Forster reported a null effect of ambiguity in a semantic categorization task (i.e., "Is it an animal?"). To perform this task, participants would need to extensively engage semantic processing to settle on a particular meaning for the presented word. Thus, an ambiguity disadvantage would certainly be the expected result in Forster's task.

The fact that there were no differences in RTs for ambiguous and unambiguous words in Forster's (1999) experiments prompted us to reevaluate the conclusions drawn from previous studies (including our own) in which an ambiguity disadvantage in semantically based tasks was taken to indicate that semantic ambiguity slows the process of meaning activation. Is there an alternative explanation for those findings? Consider first the semantic categorization experiments reported in Hino et al. (2002). In those experiments, we observed an ambiguity disadvantage in semantic categorization for a relatively broad semantic category (living things). In contrast, Forster's animal category is narrower and more clearly defined. Although decisions about both types of categories require semantic activation, the two tasks might differ in the nature of the decision-making process. Performance in the semantic categorization task (and in most, if not all, semantically based tasks) is a function of both the meaning activation process and a decision-making process. These two processes probably overlap in time, but they would be sufficiently distinct so that they could provide separate sources for behavioral effects. We are, of course, not the first to suggest that the meaning activation process and decision-making process in certain semantic tasks might be somewhat separable. Balota and Paul (1996) suggested that the relatedness decision task involves access of meanings (for the two words in each stimulus pair) and also a comparison process between the meanings of the two stimuli. They also argued that effects observed in the relatedness decision task may be due to the comparison process and not to meaning access per se.

The decision-making process in any semantically based task would likely vary as a function of task demands. Recently, we (Hino, Pexman, & Lupker, 2004) considered this possibility more extensively by examining how the nature of the semantic categorization task modulates ambiguity effects. We provided results demonstrating that easier, narrower semantic decisions do not produce an ambiguity disadvantage (replicating Forster, 1999), whereas more difficult semantic decisions do produce an ambiguity disadvantage (replicating Hino et al., 2002). The most direct implication of these results is that the ambiguity disadvantage in a semantic categorization task is a function of the task-dependent decision-making process and not a function of the common meaning activation process.

Consider next the relatedness decision tasks reported by Gottlob et al. (1999) and Piercey and Joordens (2000). In these experiments, the critical words were always presented on the "yes" (related) trials. The ambiguity disadvantage observed on those trials was attributed to the process of meaning activation, which was assumed to be more difficult for ambiguous words (with multiple semantic representations) than for unambiguous words (with single semantic representations). Alternatively, it is equally plausible that the ambiguity disadvantage was actually a function of the decision-making process. The related trials involved word pairs like *bat–vampire*. *Bat* is ambiguous, and responses were slower to these types of pairs. It is quite possible, however, that this was due to the fact that one of *bat*'s meanings is unrelated to *vampire* and the unrelated meaning of *bat* (i.e., baseball bat) could have inclined participants toward a "no" (incorrect) response. Thus, responses would have been slower and more error prone for the ambiguous pairs not because of semantic competition produced by the nature of the meaning activation process but, instead, because of response competition in the decision-making process. One way to test this alternative explanation would be to examine performance on the "no" (unrelated) trials. There would be no response competition on those trials because all of the ambiguous words' meanings would be unrelated to the paired word (e.g., *bank–vampire*). Nonetheless, if the ambiguity disadvantage is due to the process of meaning activation, then the disadvantage should be observed on unrelated trials. In this article, we examine this prediction.

The notion that the ambiguity disadvantage in semantically based tasks is caused by the decision-making process (and not the meaning activation process) is quite consistent with previous research on lexical ambiguity and sentence processing. For instance, Duffy, Morris, and Rayner (1988) examined the effects of ambiguity and context in an eye movement study. They found an ambiguity disadvantage in gaze durations for balanced target words (ambiguous words with two equally likely meanings) but only when the preceding context was neutral (see also Rayner & Duffy, 1986). When the preceding context disambiguated the target word, no ambiguity disadvantage was observed. Other aspects of their data suggested that this null effect could not be due simply to selective access of the context-relevant meaning in the disambiguating prior context condition. As those authors noted, "if accessing multiple meanings per se is time consuming, we should have found lengthened gaze durations across all conditions" (Duffy et al., 1988, p. 442). They therefore concluded that the ambiguity disadvantage should be attributed to "the stage which follows lexical access" (p. 442). In sentence processing, this post-access stage would likely involve integration of word meaning with context information. Successful integration would depend on the selection of one meaning; for ambiguous words, the irrelevant meaning would likely compete for selection, which would delay the integration process.

To recap, if the ambiguity disadvantage in a relatedness decision task is caused by the decision-making process, then no ambiguity disadvantage should be observed on "no" trials in that task. In contrast, if the ambiguity disadvantage is due to the process of meaning activation, then an ambiguity disadvantage should be observed on "no" trials. We thought it important to first establish that our selected stimuli produce the typical ambiguity advantage in LDTs. As such, Experiment 1 was an LDT involving the word stimuli that would be used in Experiment 2. Experiment 2 was a relatedness decision task in which we presented the critical word stimuli on "no" (unrelated) trials. Our experimental stimuli were low- and high-frequency, ambiguous and unambiguous words.

Experiment 1

Method

Participants. Forty University of Calgary undergraduate students participated in Experiment 1 for bonus credit. All participants reported that English was their first language and had normal or corrected-to-normal vision.

Stimuli. The word stimuli for Experiment 1 were of four types: low-frequency ambiguous, low-frequency unambiguous, high-frequency ambiguous, and high-frequency unambiguous. We selected ambiguous and unambiguous words for this experiment by using a procedure similar to that described in several previous articles (e.g., Hino & Lupker, 1996; Hino et al., 2002; Pexman & Lupker, 1999). That is, we first asked 30 undergraduate students to rate a large set of potential words for familiarity (1 = *very unfamiliar*, 7 = *very familiar*) and number of meanings (NOM; 0 = *no meaning*, 1 = *one meaning*, 2 = *more than one meaning*). The selected ambiguous words all had NOM ratings greater than 1.5, whereas the unambiguous words all had NOM ratings less than 1.2. Word frequency was manipulated such that low-frequency words had frequencies of less than 28 per million and high-frequency words had frequencies of greater

Table 1
Mean Characteristics for Word Stimuli Used in Experiments 1 and 2

Word type	Example	*n*	Frequency	Subjective familiarity	NOM
Low-frequency ambiguous	*seal*	15	13.60	3.79	1.77
Low-frequency unambiguous	*lamp*	15	11.07	3.52	1.05
High-frequency ambiguous	*club*	15	200.33	4.69	1.79
High-frequency unambiguous	*food*	15	184.60	5.02	1.04

Note. Frequency = Kučera and Francis (1967) word frequency count per million; NOM = mean number of meanings rating.

than 80 per million (Kučera & Francis, 1967). Mean frequencies, familiarity ratings, and NOM ratings for the 15 words of each type are provided in Table 1.[1] The word stimuli used in Experiment 1 are listed in boldface in Appendix A.

The 60 nonword stimuli for the lexical decision task in Experiment 1 were taken from the set of pronounceable, nonpseudohomophonic nonwords (e.g., SLINT) used in Pexman and Lupker (1999).

Procedure. On each trial, a letter string was presented in the center of a 17-inch Sony Trinitron monitor controlled by a MacIntosh G3 computer and was presented using PsyScope (Cohen, MacWhinney, Flatt, & Provost, 1993). Lexical decision responses were made by pressing either the left button (labeled *nonword*) or the right button (labeled *word*) on a PsyScope response box (New Micros Inc., Dallas, Texas).

Participants first completed 12 practice trials with verbal feedback about incorrect responses. On each trial, the target was presented until the participant responded. The intertrial interval was 2 s. Stimuli were presented in a different random order for each participant.

Results and Discussion

In Experiment 1, a trial was considered an error and was excluded from the response time (RT) analysis, if the RT was longer than 1,500 ms or shorter than 250 ms (less than 1% of trials) or if participants made an incorrect response (3.10% of trials). Mean RTs and error percentages are presented in Table 2. RT and error analyses were conducted using participants and, separately, items as random factors.[2]

For word responses, there was an interaction of ambiguity and frequency in the RT analysis, $F_s(1, 39) = 25.04$, $p < .01$, $MSE = 831.42$; $F_i(1, 56) = 5.70$, $p < .05$, $MSE = 1{,}341.49$, and also in the error analysis, $F_s(1, 39) = 7.74$, $p < .01$, $MSE = 12.90$; $F_i(1, 56) = 4.19$, $p < .05$, $MSE = 9.35$. The nature of this interaction is evident in Table 2. The ambiguity advantage was observed only for low-frequency words. Although driven by the effect for low-frequency words, there was a main effect of ambiguity in the RT analysis, $F_s(1, 39) = 18.05$, $p < .01$, $MSE = 938.03$; $F_i(1, 56) = 4.41$, $p < .05$, $MSE = 1{,}341.49$, and in the error analysis, $F_s(1, 39) = 7.19$, $p < .05$, $MSE = 10.98$; $F_i(1, 56) = 3.37$, $p = .07$, $MSE = 9.35$. There was also a main effect of frequency in the RT analysis, $F_s(1, 39) = 106.78$, $p < .01$, $MSE = 2{,}263.64$; $F_i(1, 56) = 66.60$, $p < .01$, $MSE = 1{,}341.49$, and in the error analysis, $F_s(1, 39) = 17.29$, $p < .01$, $MSE = 24.13$; $F_i(1, 56) = 17.29$, $p < .01$, $MSE = 9.35$.

The purpose of Experiment 1 was to determine whether the word stimuli selected for Experiment 2 produced the typical ambiguity advantage in LDTs. This seemed to be the case. The stimuli produced a robust ambiguity advantage, albeit only for low-frequency words. The fact that the effect was only observed for low-frequency words is reasonably consistent with the feedback account. For low-frequency words, responses are slower and thus there is more time for semantic feedback to influence orthographic activation. Because ambiguous words tend to have more extensive (richer) semantic representations, there is stronger feedback for ambiguous words, which generates a response advantage. For high-frequency words, responses are sometimes made before semantic feedback can have a significant impact on orthographic activation, and, therefore, there will be situations where no ambiguity effect is observed for high-frequency words in LDTs, as in Experiment 1.

Experiment 2

The purpose of Experiment 2 was to establish whether the word stimuli from Experiment 1 produce an ambiguity disadvantage

Table 2
Mean Response Times and Error Percentages for Experiment 1 (Lexical Decision Task)

	RT		Errors		Ambiguity effect	
Stimulus type	*M*	*SE*	*M*	*SE*	RT	Errors
Low-frequency ambiguous	567	5.90	2.50	0.69	42	3.00
Low-frequency unambiguous	609	7.75	5.50	0.97		
High-frequency ambiguous	513	4.64	0.83	0.38	−2	−0.16
High-frequency unambiguous	511	4.90	0.67	0.34		
Nonword	639	5.11	3.83	0.56		

Note. RT = response time.

[1] We checked whether differences in the mean word characteristics presented in Table 1 were significant. For low-frequency ambiguous and unambiguous words, there were no significant differences in frequency ($t < 1$) or familiarity ratings, $t(28) = 1.36$, but there was, as intended, a significant difference in NOM ratings, $t(28) = 16.79$, $p < .01$. Similarly, for high-frequency ambiguous and unambiguous words, there were no significant differences in frequency ($t < 1$) or familiarity ratings, $t(28) = -1.53$, but there was a significant difference in NOM ratings, $t(28) = 21.17$, $p < .01$.

[2] The items in Experiment 1 were not selected randomly. The implication is that items should not be treated as a random factor in these analyses, because to do so would be to violate a number of assumptions underlying the analysis of variance model (see Wike & Church, 1976). Although we will be reporting results of items analyses for the interested reader, we will not be basing our conclusions on them.

when presented on “no” (unrelated) trials in a relatedness decision task.

Method

Participants. Seventy-eight University of Calgary undergraduate students participated in Experiment 2 for bonus credit. All participants reported that English was their first language and had normal or corrected-to-normal vision. There were two versions of the experiment because the position of words within each pair was manipulated between participants. Participants were assigned to each version of the task by their order of appearance at the laboratory such that Participant 1 was assigned to Version 1, Participant 2 to Version 2, and so on.

Stimuli. The 60 experimental words used in Experiment 1 were presented in Experiment 2 in the unrelated word pairs. A large number of potential related word pairs were taken from previous studies in which semantic relatedness was examined (Borowsky & Besner, 1993; Lupker, 1984; Pugh, Rexer, & Katz, 1994). From this potential set, we selected word pairs that we considered to be semantically (and not just associatively) related. We then asked 37 undergraduate students to rate each word in each pair for NOM. On the basis of these ratings, we chose related word pairs such that 30 pairs involved one ambiguous word (NOM rating for the ambiguous word > 1.5; e.g., *shirt–tie*, where *tie* is ambiguous) and another 30 pairs did not (NOM rating for both words < 1.35; e.g., *truck–car*).

To create the unrelated word pairs, each experimental word was paired with a word from the set of words that we had considered but did not choose for the related trials. Across the four experimental word conditions, we attempted to match familiarity and NOM for the paired unrelated words. As such, mean familiarity and NOM values for the paired unrelated words were as follows: for those paired with low-frequency ambiguous words, 4.09 and 1.09; for those paired with low-frequency unambiguous words, 4.39 and 1.10; for those paired with high-frequency ambiguous words, 3.92 and 1.13; and for those paired with high-frequency unambiguous words, 4.32 and 1.11, respectively. To summarize, the stimuli for this task involved 15 unrelated word pairs containing a low-frequency ambiguous word, 15 unrelated word pairs containing a low-frequency unambiguous word, 15 unrelated word pairs containing a high-frequency ambiguous word, 15 unrelated word pairs containing a high-frequency unambiguous word, 30 related word pairs containing one ambiguous word, and 30 related word pairs containing no ambiguous word.

Word position in pairs was counterbalanced across items and across participants. Thus, for unrelated pairs, participants were presented with seven or eight of the experimental words of each type in the first position and seven or eight of the experimental words of each type in the second position in the pair. Further, for a given unrelated item (e.g., *seal–jury*), half of the participants were presented with the experimental word in the first position (*seal–jury*) and half of the participants were presented with the experimental word in the second position (*jury–seal*). For related pairs, the same type of manipulation was applied. Therefore, for a given pair (e.g., *shirt–tie*), half of the participants were presented with *shirt–tie* and the other half were presented with *tie–shirt*. All of these stimuli are listed in Appendix A.

Procedure. The procedure for Experiment 2 was similar to that used in Experiment 1, except that on each trial two words were presented side-by-side and relatedness decisions were made by pressing either the left button (labeled *no*) or the right button (labeled *yes*) on a PsyScope response box.

Results and Discussion

In Experiment 2, a trial was considered an error and was excluded from the RT analysis, if the RT was longer than 1,750 ms or shorter than 250 ms (less than 1% of trials) or if participants made an incorrect response (6.40% of trials). Mean RTs and error percentages are presented in Table 3.

Unrelated word pairs (“no” responses). For the experimental words presented in unrelated word pairs, there was no effect of ambiguity in the RT analysis, $F_s < 1$; $F_i < 1$, or the error analysis, $F_s(1, 77) = 2.80$, $p = .10$, $MSE = 50.36$; $F_i < 1$. Similarly, ambiguity did not interact with either frequency or word position. The only significant effect on unrelated trial data was the interaction of word position and frequency, which was significant by participants only in the RT analysis, $F_s(1, 77) = 10.67$, $p < .01$, $MSE = 4{,}753.39$; $F_i < 1$. The nature of this interaction was that responses were somewhat faster for high-frequency words presented in the second position in the unrelated word pairs. Essentially, there was a tendency to judge unrelatedness more quickly when the second word in the pair was relatively more familiar. It was also the case, however, that error rates were slightly higher for high-frequency words in the second position, so this effect may be due to a speed–accuracy trade-off.

Related word pairs (“yes” responses). The related word pairs were essentially filler stimuli, and, thus, the interpretation of the

Table 3
Mean Response Times and Error Percentages for Experiment 2 (Relatedness Decision Task)

	Ambiguous word in first position						Ambiguous word in second position					
	RT		Errors		Ambiguity effect		RT		Errors		Ambiguity effect	
Stimulus type	*M*	*SE*	*M*	*SE*	RT	Errors	*M*	*SE*	*M*	*SE*	RT	Errors
Unrelated word pairs (“no” trials)												
LF ambiguous	942	10.72	3.96	0.77	4	0.86	942	10.82	4.24	0.79	9	−0.67
LF unambiguous	946	11.18	4.82	0.83			951	10.31	3.57	0.73		
HF ambiguous	963	11.79	4.41	0.82	−10	1.09	928	10.23	4.13	0.83	17	2.73
HF unambiguous	953	11.11	5.50	0.92			945	10.21	6.86	0.98		
Related word pairs (“yes” trials)												
Ambiguous	830	7.50	10.68	0.86	−60	−7.09	831	7.60	13.42	0.96	−64	−8.72
Unambiguous	770	6.73	3.59	0.52			767	6.65	4.70	0.59		

Note. HF = high frequency; LF = low frequency; RT = response time.

results for these pairs must be done somewhat cautiously because we did not control their word frequency or relatedness in a systematic way. For related word pairs, there was a significant ambiguity disadvantage. RTs were slower, $F_s(1, 77) = 120.60$, $p < .01$, $MSE = 2{,}548.17$; $F_i(1, 58) = 5.18$, $p < .05$, $MSE = 31{,}808.60$, and error rates were higher, $F_s(1, 77) = 130.85$, $p < .01$, $MSE = 37.25$; $F_i(1, 58) = 4.96$, $p < .05$, $MSE = 373.01$, when the pairs included an ambiguous word than when the pairs did not include an ambiguous word. None of the effects involving word position were significant. Responses did not differ as a function of whether the ambiguous word was presented first or second.

Results for unrelated word pairs showed no evidence of an ambiguity effect. This was probably not due to a lack of power for unrelated trials. Using the *MSE* from unrelated trials, we estimated that, for the unrelated pairs, the power to detect an ambiguity effect of the size observed on related trials was 0.93. Thus, these results provide support for the claim that the ambiguity disadvantage observed in previous studies for related word pairs (Gottlob et al., 1999; Piercey & Joordens, 2000) was a function of response competition in the decision-making process.

In addition to the power issue, there are a couple of other issues concerning Experiment 2 that should be discussed at this point. One issue concerns our reliance on "no" trials in drawing our conclusion. Could one argue, for example, that "no" trials in a relatedness decision task are somehow insensitive to the semantic processing differences that produce effects on "yes" trials? The answer, based on the previous literature, would appear to be no. Consider, for example, the results of Klinger and Greenwald (1995). Their experiment involved a relatedness decision task with semantic primes (some masked and some visible) being presented before the first word in each target pair. For instance, the prime *hawk* preceded the related pair *eagle–falcon* (a "yes" trial) or the unrelated pair *eagle–polka* (a "no" trial). Significant priming was observed for both "yes" and "no" trials. That is, the meaning activation process was facilitated by semantically related prime words, and this facilitation was observed even on "no" trials. Klinger and Greenwald's results are, therefore, certainly not consistent with the idea that "no" trials are insensitive to semantic factors.

Luo, Johnson, and Gallo (1998), using homophones, also demonstrated semantic effects on unrelated trials in a relatedness decision task. Responses for word pairs involving a homophone that sounded like a related word (e.g., LION-BARE) were compared to responses for word pairs involving a homophone that sounded like an unrelated word (e.g., LION-BEAN). The correct response in both cases is "no." The results showed a disadvantage for the former pairs. The authors attributed the results to "extra effort taken to inhibit incorrect lexical entries accessed by homophones" (Luo, Johnson, & Gallo 1998, p. 836). The important point, for our purposes, however, is that the semantic information activated by the homophone clearly affected latencies on "no" trials, indicating again that those trials are not insensitive to semantic factors.

Post Hoc Analyses

Although there is evidence that "no" trials are sensitive to semantic variables in semantic relatedness decision tasks in the literature, it is still, of course, possible that the participants in Experiment 2 were using some sort of response strategy that, in general, made the "no" trials insensitive to semantic (or other) effects. One might wonder why, if frequency effects were observed in the LDT in Experiment 1, similar effects were not observed in the relatedness decision task in Experiment 2. To examine these issues, we conducted a set of post hoc analyses. The one factor that should affect relatedness decision responses on both "yes" and "no" trials is the degree of relatedness of the paired words (even though any relatedness measures for the unrelated pairs will, by definition, have a very small variance). Thus, we collected relatedness ratings for all of the word pairs used in Experiment 2 (both related and unrelated). To do so, we asked a group of 30 undergraduates at the University of Calgary to evaluate each pair of words and to rate the degree of relatedness of the words in the pair on a 7-point scale. Using these ratings, as well as other word characteristics (frequency, ambiguity, word length), we ran multiple regression analyses to examine the relationships of these variables to responses on "no" and "yes" trials in Experiment 2. On "no" trials, the only predictor variable that had a significant, unique relationship with RT or errors was relatedness. That is, higher relatedness ratings were associated with longer RTs and more response errors. On "yes" trials, the only predictor variables that had significant, unique relationships with RT or errors were ambiguity and relatedness. That is, word pairs that included an ambiguous word were associated with slower responses, whereas word pairs that were more strongly related were associated with faster responses and fewer errors.

These results show that even though ambiguity influences latency on related trials there is no evidence that it influences performance on unrelated trials. Further, word frequency did not have a significant impact on either related or unrelated trials; the relatedness decision task itself does not seem sensitive to that variable. In contrast, relatedness effects were observed on both related and unrelated trials in spite of the fact that there was very little variance in the relatedness ratings for the unrelated pairs. This analysis provides reasonable evidence that effects can be observed on unrelated trials in the relatedness decision task. An ambiguity effect is simply not one of them.

An additional issue in Experiment 2 is the fact that we used different words in the related and unrelated trials. This raises the possibility that the lack of an ambiguity effect on unrelated trials was attributable to that particular set of items. We cannot be certain that the experimental words, which did not produce an ambiguity disadvantage on unrelated trials, would have produced the expected ambiguity disadvantage on related trials. In addition, on the related trials in Experiment 2, we did not control which of the ambiguous words' meanings (dominant or subordinate) were related to the meaning of the word it was paired with, as Gottlob et al. (1999) had done. In an effort to examine these methodological issues more closely, we devised Experiment 3 in which the same target words were presented on both related trials (Experiments 3a and 3b) and unrelated trials (Experiment 3c), and in both dominantly related pairs (Experiment 3a) and subordinately related pairs (Experiment 3b). Experiment 3 is, in part, a replication of Gottlob et al., because we used their target words but added an experiment in which their ambiguous and unambiguous words were presented on unrelated trials.

Experiment 3

Method

Participants. Participants were University of Calgary undergraduate students who participated for course credit. There were 32 participants in each of Experiments 3a and 3b and 34 participants in Experiment 3c. All participants reported that English was their first language and had normal or corrected-to-normal vision.

Stimuli. The stimuli for Experiment 3 were the 14 semantically ambiguous and 14 unambiguous words used by Gottlob et al. (1999). The ambiguous words were paired with dominantly related words in Experiment 3a and with subordinately related words in Experiment 3b. The unambiguous words were paired with the same related words in Experiments 3a and 3b. The word pairs used in Experiments 3a and 3b were the same pairs devised by Gottlob et al. In Experiment 3c, all experimental stimuli were paired with unrelated words.

Gottlob et al. (1999) had collected relatedness ratings for their related word pairs (both dominantly and subordinately related pairs, used here in Experiments 3a and 3b). For our purposes, it was also necessary to collect relatedness ratings for the unrelated word pairs to be used in Experiment 3c, particularly because analyses in Experiment 2 showed that relatedness ratings were a significant predictor of latency and errors. To create unrelated pairs that contained the ambiguous experimental words for Experiment 3c, we initially re-paired the dominantly related mates of those words used in Experiments 3a with different experimental words. Two potential unrelated pairs were created for each ambiguous word. For the unambiguous words, their mates were also re-paired with different experimental words in two different ways. Thus, two unrelated pairs were created for each of the unambiguous words. Forty-eight University of Calgary undergraduates were asked to rate these potential unrelated pairs for use in Experiment 3c. Twenty-four participants were asked to rate one set of potential pairs and 24 participants were asked to rate the other set of potential pairs, so that no participant saw the same target word twice. We then selected unrelated mates for the ambiguous and unambiguous experimental words such that mean relatedness ratings were comparable for the ambiguous and unambiguous word sets. For the ambiguous word pairs, the mean relatedness rating was 1.70; whereas for unambiguous words, the mean relatedness rating was 1.68 ($t < 1$). As such, the relatedness ratings were comparable for the word pairs created for the ambiguous and unambiguous word sets. Word pair length was also comparable for the ambiguous and unambiguous word sets, with pairs in both sets averaging 9.70 letters in length.

To create 28 unrelated pairs for Experiments 3a and 3b and 28 related pairs for Experiment 3c, we used a subset of the related pairs from Experiment 2. These words were re-paired to be unrelated in Experiments 3a and 3b, and they appeared in their related pairs in Experiment 3c. All of these stimuli are presented in Appendix B.

Procedure. The procedure was the same as that described for Experiment 2. In particular, word pairs were presented simultaneously on each trial.

Results and Discussion

In Experiment 3, a trial was considered an error and was excluded from the RT analysis, if the RT was longer than 1,900 ms or shorter than 250 ms (less than 1% of trials in each of Experiments 3a, 3b, and 3c) or if participants made an incorrect response (6.12% of trials in Experiment 3a, 8.43% of trials in Experiment 3b, and 8.02% of trials in Experiment 3c). Mean RTs and error percentages are presented in Table 4.

In Experiment 3a, there was a main effect of ambiguity that was significant by participants in the RT analysis, $F_s(1, 31) = 18.86$, $p < .01$, $MSE = 5{,}011.20$; $F_i(1, 26) = 2.79$, $p = .11$, $MSE = 18{,}071.15$, but not in the error analysis, $F_s(1, 31) = 1.14$, $p = .29$, $MSE = 95.22$; $F_i < 1$. Thus, RTs were slower when related pairs included an ambiguous word. Ambiguity did not interact with position (whether the target word appeared first or second in the pair; $F_s < 1$; $F_i < 1$).

In Experiment 3b, there was a main effect of ambiguity that was significant by participants in the RT analysis, $F_s(1, 31) = 12.59$, $p < .01$, $MSE = 9{,}088.15$; $F_i(1, 26) = 3.11$, $p = .09$, $MSE = 27{,}113.03$, and in the error analysis, $F_s(1, 31) = 41.31$, $p < .01$, $MSE = 123.17$; $F_i(1, 26) = 5.28$, $p < .05$, $MSE = 430.91$. Thus, RTs were slower and more errors were made when related pairs included an ambiguous word. Again, ambiguity did not interact with position in the RT analysis, $F_s(1, 31) = 2.05$, $p = .16$, $MSE = 7{,}657.26$; $F_i < 1$, or in the error analysis, $F_s(1, 31) = 1.99$, $p = .17$, $MSE = 167.56$; $F_i(1, 26) = 2.13$, $p = .16$, $MSE = 57.73$.

In Experiment 3c, the effect of ambiguity was not significant in the RT analysis, $F_s(1, 33) = 1.72$, $p = .20$, $MSE = 5{,}703.59$; $F_i < 1$. It was also not significant in the error analysis, although there was a tendency toward an ambiguity advantage, with fewer errors for unrelated pairs that included an ambiguous word, $F_s(1, 33) = 3.22$, $p = .08$, $MSE = 59.25$; $F_i(1, 26) = 1.95$, $p = .17$, $MSE = 50.17$. The trend toward lower error rates for ambiguous word pairs was driven by the results from trials in which the ambiguous word was in the second position (see Table 4). Note also that the RTs in this situation showed the opposite trend (i.e., there was some hint of an ambiguity disadvantage), which suggests a small speed–accuracy trade-off. Nonetheless, ambiguity did not interact with position in the RT analysis ($F_s < 1$; $F_i < 1$) or in the error analysis, $F_s(1, 33) = 2.12$, $p = .16$, $MSE = 50.76$; $F_i(1, 26) = 2.87$, $p = .10$, $MSE = 25.45$. The lack of an ambiguity effect here was probably not due to a lack of power for unrelated trials. Using the *MSE* from unrelated trials in Experiment 3c, we estimated that, for the unrelated pairs, the power to detect an ambiguity effect of the size observed on related trials was 0.98.

As in Experiment 2, we again ran multiple regression analyses to examine the relationships between the predictor variables of ambiguity, relatedness ratings, word frequency and word length, and the criterion variables of RT and error rate in Experiment 3. For Experiment 3a, the predictor variables that had significant, unique relationships with RT and errors were ambiguity and relatedness. Again, word frequency and word length were not significant predictors. For Experiment 3b, the predictor variable that had significant, unique relationships with RT and errors was ambiguity, and the relationships for relatedness approached significance. For Experiment 3c, we again observed a significant relationship for relatedness (with errors) but not for ambiguity.

The present results are consistent with those from Experiment 2. Although an ambiguity disadvantage was observed for responses on related trials, there was no evidence of an ambiguity disadvantage on unrelated trials. Further, word frequency had no significant impact on performance in this task, and, again, relatedness effects were observed on both related and unrelated trials.

Table 4
Mean Response Times and Error Percentages for Experiment 3 (Relatedness Decision Task with Gottlob et al.'s, 1999, Target Stimuli)

	Ambiguous word in first position						Ambiguous word in second position					
	RT		Errors		Ambiguity effect		RT		Errors		Ambiguity effect	
Stimulus type	*M*	*SE*	*M*	*SE*	RT	Errors	*M*	*SE*	*M*	*SE*	RT	Errors
Experiment 3a (with dominantly related mates)												
Related word pairs ("yes" trials)												
Ambiguous	854	18.09	7.14	1.73	−52	−0.25	866	17.57	10.29	2.02	−64	−4.43
Unambiguous	802	14.10	6.89	1.68			802	18.71	5.86	1.61		
Unrelated word pairs ("no" trials)												
Filler words	929	9.95	5.32	0.79								
Experiment 3b (with subordinately related mates)												
Related word pairs ("yes" trials)												
Ambiguous	904	20.75	21.33	2.71	−76	−16.44	886	17.56	16.39	2.48	−55	−9.40
Unambiguous	828	16.07	4.89	1.50			831	17.01	6.99	1.66		
Unrelated word pairs ("no" trials)												
Filler words	962	9.11	4.08	0.60								
Experiment 3c (with unrelated mates)												
Related word pairs ("yes" trials)												
Filler words	812	9.53	12.86	1.10								
Unrelated word pairs ("no" trials)												
Ambiguous	943	18.05	2.86	1.08	−25	4.33	935	17.02	2.86	1.10	−3	0.35
Unambiguous	918	16.39	7.19	1.73			932	16.84	3.21	1.22		

Note. RT = response time.

The pattern of ambiguity effects in Experiment 3, arising on "yes" trials regardless of whether the mate was related to the dominant meaning of the experimental word or the subordinate meaning of the experimental word but not on "no" trials (when using the stimuli of Gottlob et al., 1999), implies that these ambiguity effects do not appear to be due to the process of meaning activation. If they were meaning activation effects, responses should have been affected on both related and unrelated trials, because ambiguous meanings should compete for activation in the semantic units regardless of the nature of the word pair. Instead, these effects appear to be due to a different process, most likely the decision process involved in making a relatedness decision.

The results of Experiments 2 and 3 are fairly clear. One may note, however, that our procedures in these experiments did differ in one other way from the procedures used in previous studies. We presented the word pairs simultaneously, whereas Gottlob et al. (1999) and Piercey and Joordens (2000) presented their word pairs sequentially. It seems unlikely that this difference could have produced the null effects in Experiments 2 and 3c, and, in fact, it would seem that a simultaneous presentation procedure would actually be the superior procedure, because it allows less time for participants to strategically use the first stimulus. Nonetheless, the empirical question still remains as to whether we would observe an ambiguity disadvantage on "no" trials if we had used Gottlob et al.'s and Piercey and Joordens' precise procedure. Experiment 5 was conducted using the sequential presentation of the two words in each pair to investigate this possibility.

Experiment 5 also gave us an opportunity to investigate another associated issue. In Experiments 1, 2, and 3, we did not examine the relatedness of the multiple meanings for the ambiguous words (i.e., how closely the various meanings of an ambiguous word are related to one another). Although the relatedness of meaning factor was not examined by Gottlob et al. (1999) or Piercey and Joordens (2000), it has been gaining attention recently in the ambiguity literature. The idea is that it is possible to draw a linguistic distinction between homonyms (ambiguous words with unrelated meanings) and polysemous words (ambiguous words with related meanings or senses), and researchers have been investigating the extent to which this distinction is also important psychologically. For instance, Azuma and Van Orden (1997) reported that the advantage for ambiguous words in LDTs arises only for words with low relatedness among meanings. Rodd, Gaskell, and Marslen-Wilson (2002) attempted to disentangle effects of multiple senses (related meanings) and effects of multiple meanings (unrelated meanings) and found an advantage in LDTs for words with many senses and, in the same task, some evidence for an inhibitory effect of ambiguity. Thus, they argued that previous reports of the ambiguity advantage may have been due to the effect of multiple senses and not to the effect of multiple meanings.

In contrast, Klein and Murphy (2001; see also Klein & Murphy, 2002) reported data indicating that this linguistic distinction between homonymy and polysemy appears to have little consequence for semantic representation. Participants in their study were presented with polysemous or homonymic nouns paired with modifiers (e.g., wrapping *paper*, commercial *bank*). Whereas prior presentation of the polysemous nouns (wrapping *paper*) facilitated recognition memory and sensicality judgments for the same nouns used in the same sense (shredded *paper*), they did not facilitate responses for the same nouns used in a different sense (daily *paper*). The same was true for homonymic nouns. That is, presentation of commercial *bank* facilitated responses to savings *bank* but not to muddy *bank*. The authors concluded that for both types of words, the multiple meanings or related senses are represented separately in the semantic system.

In the Hino et al. (2004) article, we also considered the influence of relatedness of meanings; according to most PDP models, that variable should influence the speed of semantic coding. That is, for a word with related meanings (e.g., *paper*), the different semantic representations for meanings of the word should share features. For a word with unrelated meanings (e.g., *bank*), the different semantic representations should share few, if any, features. Thus, the mappings from orthography to semantics for ambiguous words with related meanings should be somewhat more consistent than the mappings for ambiguous words with unrelated meanings. This should produce a benefit for words with more related meanings in semantically based tasks (and, possibly, a benefit for words with less related meanings in LDTs). Yet, we observed a relatedness of meanings advantage only in difficult categorization tasks and a null effect of relatedness of meanings in easier categorization tasks and in LDTs. Given the mixed findings in these previous studies, there is clearly a need for additional research on the effects of relatedness of meanings.

To further investigate these issues, we developed a new set of items, which allowed us to manipulate both ambiguity and relatedness of meanings. We presented these items in LDTs (Experiment 4) and also in a relatedness decision task on related trials (Experiments 5a and 5b) and unrelated trials (Experiment 5c). We presented the two words in each pair sequentially as done by Gottlob et al. (1999) and Piercey and Joordens (2000). Experiments 4 and 5 involved Japanese words written in Katakana. In our previous research using Japanese Katakana words, we have consistently found that the effects mimic those found with English stimuli. Compare, for instance, synonymy effects and ambiguity effects in LDTs using Japanese Katakana stimuli reported in Hino, Lupker, and Pexman (2002) with synonymy effects in LDTs using Dutch and English stimuli in Pecher (2001) and ambiguity effects in LDTs using English stimuli in Hino and Lupker (1996) and Pexman and Lupker (1999).

The experimental words in Experiments 4 and 5 are normally written in Katakana. Because the Katakana script is shallow, the character-to-sound relationships are quite consistent for these words. In addition, in contrast to a number of Kanji words, Katakana words are not generally homophonic because most of them are loan words from English. In fact, none of our experimental Katakana words are homophones according to a computer-based dictionary with 36,780 word entries (National Language Research Institute, 1993). Therefore, these Katakana words would be suitable for examining the effects that arise due to the nature of orthographic-to-semantic mappings without having to worry about confounding effects due to phonology (e.g., regularity, consistency).

Experiment 4

Method

Participants. Twenty-six Chukyo University undergraduate students participated in Experiment 4 for course credit. All participants reported that Japanese was their first language and had normal or corrected-to-normal vision.

Stimuli. The critical word stimuli for Experiment 4 were of three types: ambiguous words with less related meanings, ambiguous words with more related meanings, and unambiguous words. We selected the critical words based on subjective ratings collected by Hino et al. (2004). That is, Hino et al. collected ratings of subjective familiarity, NOM, and number of synonyms for 120 ambiguous Katakana words and 120 unambiguous Katakana words with nonliving thing meanings.

For the subjective familiarity ratings, Hino et al. (2004) asked 42 participants to rate the subjective familiarity of these words (1 = *very unfamiliar*, 7 = *very familiar*). For the NOM ratings, Hino et al. asked 41 participants to count the NOMs for these words (0 = *no meaning*, 1 = *one meaning*, 2 = *more than one meaning*). For the number of synonym ratings, Hino et al. asked 36 participants to count the number of synonyms for each word.

In addition, for the ambiguous words, Hino et al. (2004) evaluated the relatedness of meanings using two types of subjective ratings. First, 41 participants were asked to think of all the meanings for each of the 120 ambiguous words and to rate the relatedness of these meanings (1 = *unrelated*, 7 = *related*). Second, using a technique similar to that used by Azuma and Van Orden (1997), Hino et al. asked 50 participants to write down all the meanings they could think of for the 120 ambiguous words and then classified participants' responses as the same meaning or different meanings based on an unabridged Japanese dictionary (Umesao, Kindaichi, Sakakura, & Hinohara, 1995). After classifying the responses, Hino et al. counted meanings given by more than 5 participants (10%) as meanings for each word. This resulted in 72 ambiguous words selected from the set of 120 ambiguous words. For these 72 words, all NOM ratings were more than 1.3, and there were at least two meanings that were generated by at least 6 participants (more than 5%). Then, for each word, the two meanings were presented together, and 36 participants were asked to rate the degree of relatedness of each pair of the meanings (1 = *unrelated*, 7 = *related*). Based on these ratings, 28 ambiguous words with less related meanings and 28 words with more related meanings were selected.

In Experiments 5a and 5b, the experimental words were to be presented with related words (to evoke "yes" responses in the relatedness decision task). Thus, we narrowed our experimental word set further by evaluating the relatedness of potential related word pairs. That is, the 80 potential words (28 ambiguous words with less related meanings, 28 ambiguous words with more related meanings, and 24 unambiguous words) were paired with potential related words (written in either Katakana, Hiragana, Kanji, or a mixture of Kanji and Hiragana) based on the experimenters' intuition. For the 28 ambiguous words with less related meanings, 12 words were paired with 4 related words (2 dominant and 2 subordinate) and 16 words were paired with 2 related words (1 dominant and 1 subordinate), resulting in 80 potential pairs in total. Similarly, for the 28 ambiguous words with more related meanings, 18 words were paired with 4 related words (2 dominant and 2 subordinate) and 10 words were paired with 2 related words (1 dominant and 1 subordinate), resulting in 92 potential pairs in total. Finally, for the 24 unambiguous words, 39 pairs were created: 15 words were paired with 2 related words, and 9 words were paired with 1 related word.

These 211 word pairs were presented with 40 unrelated Katakana word pairs in a random order in a questionnaire, and 42 participants were asked to rate the relatedness of each pair (1 = *unrelated*, 7 = *related*). Based on these ratings, the final set of 16 ambiguous words with less related meanings, 16 ambiguous words with more related meanings, and 16 unambiguous words was selected. In addition, 2 related words (1 dominant and 1 subordinate) were selected for each ambiguous word and 1 related word was selected for each unambiguous word for use in Experiment 5. Mean characteristics for the 16 words of each type are provided in Ta-

Table 5
Mean Characteristics for Word Stimuli Used in Experiments 4 and 5

Word type	Example	*n*	FREQ	Length	Syllables	*N*	FAM	NOM	NOS	ROM-A	ROM-B	MC
Ambiguous/less related	*ring*	16	14.13	3.50	3.44	3.31	4.96	1.58	1.06	2.68	2.12	3.06
Ambiguous/more related	*home*	16	7.50	3.44	3.88	4.95	1.50	1.12	4.55	3.68	3.25	
Unambiguous	*bike*	16	11.88	3.44	3.38	3.50	5.05	1.05	1.01			

Note. FREQ = mean word frequency; *N* = mean orthographic neighborhood size; FAM = mean subjective familiarity rating; NOM = mean number of meanings rating; NOS = mean number of synonyms rating; ROM-A = mean relatedness of meanings rating based on items; ROM-B = mean relatedness of meanings rating based on meaning pairs; MC = mean meaning count based on 50 participants' responses.

ble 5.[3] These were all low-frequency Japanese Katakana words between two and five characters in length. The word stimuli presented in Experiment 5 are listed in Appendix C.

We also selected 48 Katakana written nonwords from the 90 Katakana nonwords used in Hino et al.'s (2004) NOM ratings. The mean character length of these nonwords was 3.44, ranging from 2 to 5 characters. The mean number of syllables was 3.40, ranging from 2 to 5 moras. The NOM ratings for these nonwords were all less than 0.10, with a mean of 0.01.

Procedure. On each trial, a letter string was presented in the center of a 17-inch NEC monitor. Lexical decision responses were made by pressing either the XFER key (labeled *nonword*) or the NFER key (labeled *word*) on an NEC Japanese keyboard. In all other respects, the procedure was the same as described for Experiment 1.

Results and Discussion

In Experiment 4, a trial was considered an error and was excluded from the RT analysis, if the RT was longer than 1,600 ms or shorter than 250 ms (less than 1% of trials) or if participants made an incorrect response (5.01% of trials). Mean RTs and error percentages are presented in Table 6.

For word responses, there was a main effect of word type that was significant by participants in the RT analysis, $F_s(2, 50) = 17.32$, $p < .01$, $MSE = 579.75$; $F_i(2, 45) = 2.64$, $p = .08$, $MSE = 2{,}123.92$, and in the error analysis, $F_s(2, 50) = 3.53$, $p < .05$, $MSE = 27.84$; $F_i(2, 45) = 1.99$, $p = .18$, $MSE = 30.33$. Planned comparisons further revealed that lexical decision latencies were faster for the two types of ambiguous words than for the unambiguous words. That is, the ambiguity advantage for ambiguous words with less related meanings was significant by participants in the RT analysis, $t_s(25) = 4.65$, $p < .01$; $t_i(30) = 1.82$, $p = .08$, and in the error analysis, $t_s(25) = 2.11$, $p < .05$; $t_i(30) = 1.63$, $p = .11$. The ambiguity advantage for ambiguous words with more related meanings was also significant by both participants and items in the RT analysis, $t_s(25) = 4.97$, $p < .01$; $t_i(30) = 2.21$, $p < .05$, and approached significance in the error analysis, $t_s(25) = 2.01$, $p = .06$; $t_i(30) = 1.86$, $p = .08$. For the two types of ambiguous words, RTs and errors did not differ significantly (all ts < 1).

These results show an ambiguity advantage but no effect of relatedness. The ambiguity advantage in this LDT is consistent with that reported in Experiment 1 and in many previous studies. The null effect of relatedness is consistent with results reported by Hino et al. (2004) and with the claims of Klein and Murphy (2001, 2002) but is not consistent with previous reports of a relatedness advantage in LDTs by Azuma and Van Orden (1997) and Rodd et al. (2002). We addressed possible reasons for the discrepancy with Azuma and Van Orden's results and also with Rodd et al.'s results in the Hino et al. (2004) article. We note that Azuma and Van Orden and Rodd et al. have claimed that their relatedness of meaning effects in LDTs only arise when pseudohomophones are used as nonwords. Thus, at a minimum, it appears that relatedness effects in LDTs are not pervasive. The most important fact for our present purposes, however, is that the experimental stimuli chosen for Experiments 4 and 5 produce an ambiguity advantage in an LDT.

Experiment 5

Method

Participants. Participants were Chukyo University undergraduate students who participated for course credit. There were 26 participants in each of Experiments 5a, 5b, and 5c. All participants reported that Japanese was their first language and had normal or corrected-to-normal vision.

Stimuli. The stimuli for Experiment 5 were the same experimental stimuli developed for Experiment 4, but here the stimuli were presented paired with other words. The ambiguous word stimuli were presented paired with dominantly related words in Experiment 5a and with subordinately related words in Experiment 5b. The unambiguous stimuli were presented paired with the same related words in Experiments 5a and 5b. In Experiment 5c, all experimental stimuli were presented paired with unrelated words.

As described in the Method section for Experiment 4, relatedness ratings were collected for the word pairs. For the ambiguous words with less related meanings, mean relatedness ratings were 5.12 when paired with dominantly related words and 4.94 when paired with subordinately related

[3] We checked whether differences in the mean word characteristics presented in Table 4 were significant. For the three word types, there were no significant differences in frequency, $F(2, 45) = 1.19$, $MSE = 152.39$, word length ($F < 1$), number of syllables (moras; $F < 1$), orthographic neighborhood size (N; e.g., Coltheart, Davelaar, Jonasson, & Besner, 1977; $F < 1$), subjective familiarity ratings ($F < 1$), or number of synonyms ratings, $F(2, 45) = 1.04$, $MSE = .05$. There was, as intended, a significant difference in NOM ratings for unambiguous words and ambiguous words with less related meanings, $t(30) = 11.10$, $p < .01$, and there was also a significant difference in NOM ratings for unambiguous words and ambiguous words with more related meanings, $t(30) = 10.76$, $p < .01$. NOM ratings did not differ significantly for the two types of ambiguous words ($t < 1$). Meaning counts for the two types of ambiguous words were also not significantly different ($t < 1$). In addition, relatedness of meanings ratings based on items were significantly higher for the ambiguous words with more related meanings compared to the ambiguous words with less related meanings, $t(30) = 10.81$, $p < .01$. Relatedness of meanings ratings based on meaning pairs were also higher for the ambiguous words with more related meanings compared to the ambiguous words with less related meanings, $t(30) = 6.30$, $p < .001$.

Table 6
Mean Response Times and Error Percentages for Experiment 4 (Lexical Decision Task)

	RT		Errors		Ambiguity effect		Relatedness effect	
Stimulus type	*M*	*SE*	*M*	*SE*	RT	Errors	RT	Errors
Ambiguous/less related	547	11.62	3.61	0.86	31	3.36	4	0.00
Ambiguous/more related	543	13.78	3.61	1.16	35	3.36		
Unambiguous	578	15.41	6.97	1.40				
Nonword	645	21.28	5.30	0.73				

Note. RT = response time.

words. For ambiguous words with more related meanings, mean relatedness ratings were 5.19 when paired with dominantly related words and 5.04 when paired with subordinately related words. For unambiguous pairs, the mean relatedness rating was 5.19. As such, the relatedness ratings were comparable for the dominantly related pairs of the two types of ambiguous words and the unambiguous word pairs ($F < 1$). The relatedness ratings were also comparable for the subordinately related pairs of the two types of ambiguous words and the unambiguous word pairs ($F < 1$).

In addition, there were no differences in word frequency, $F(2, 45) = 1.00$, $p = .35$, $MSE = 5{,}999.94$, word length ($F < 1$), or number of syllables ($F < 1$) across the three groups of words paired with the three types of experimental words in Experiment 5a. Similarly, there were no differences in word frequency ($F < 1$), word length ($F < 1$), or number of syllables ($F < 1$) across the three groups of words paired with the three types of experimental words in Experiment 5b.

To create unrelated word pairs for Experiments 5a and 5b, we selected 48 unambiguous Katakana words from the 120 unambiguous words involved in Hino et al.'s (2004) subjective ratings. All the NOM ratings for the 48 unambiguous words were less than 1.35. Each of these unambiguous words was paired with two related words (written in either Katakana or Kanji) based on the experimenters' intuition. These related words were then re-paired with other unambiguous words to create a collection of unrelated pairs. Each unambiguous word was paired with two unrelated words in this collection. To evaluate the degree of relatedness of these word pairs, we mixed the 96 unrelated pairs with the 80 experimental pairs (both dominantly related and subordinately related pairs for the ambiguous words and the related pairs for the unambiguous words) and listed them in a questionnaire in random order. A group of 33 participants were asked to rate the relatedness of each word pair (1 = *unrelated*, 7 = *related*).[4] Based on these ratings, we selected 48 unrelated pairs. The mean relatedness rating for these unrelated pairs was 1.61.

To create unrelated pairs containing the experimental words in Experiment 5c, we initially re-paired the dominantly related and subordinately related mates of those words used in Experiments 5a and 5b with different experimental words. Two unrelated pairs were created for each ambiguous word. For the unambiguous words, their mates were also re-paired with different experimental words in two different ways. Thus, two unrelated pairs were created for each of the unambiguous words.

To create related pairs for Experiment 5c, we initially paired the 48 Katakana words selected for the unrelated trials in Experiments 5a and 5b with two different related words. These two words were written in Katakana, Kanji, Hiragana, or a mixture of Kanji and Hiragana. The 96 unrelated pairs and 96 related pairs created in this fashion were randomly ordered and listed in a questionnaire. A different set of 33 participants was asked to rate the relatedness of each word pair (1 = *unrelated*, 7 = *related*). Based on these relatedness ratings, unrelated mates were selected for the experimental words and the 48 Katakana words to be used in related pairs. The mean relatedness ratings were 1.77 for the pairs involving the ambiguous experimental words with less related meanings, 1.82 for the pairs involving the ambiguous words with more related meanings, and 1.78 for the unrelated pairs involving the unambiguous words ($F < 1$). Across the experimental word types, there were no differences among the unrelated mates in terms of word frequency, $F(2, 45) = 1.48$, $p = .24$, $MSE = 8{,}059.27$, word length ($F < 1$), or number of syllables ($F < 1$). These ratings were also used to select 48 related pairs for Experiment 5c. The mean relatedness rating for these 48 pairs was 6.22.

Procedure. Participants were asked to decide whether the successively presented words were related or not by pressing either the "yes" (related) or "no" (unrelated) key (XFER and NFER keys, flanking the space bar) on a Japanese keyboard. In Experiment 5, each trial was initiated by a 50-ms 400-Hz beep signal. After the beep, a fixation point was presented in the center of the video monitor. One second after the onset of the fixation point, the first word of the pair was presented for 1,000 ms just above the fixation point in Katakana, Hiragana, Kanji, or a mixture of Kanji and Hiragana. Then, 50 ms after the offset of the first word, a second word was presented just above the fixation point. The experimental words were always presented second in Katakana. RTs were measured from the onset of the second word to the participant's key press. In all other respects, the procedure was the same as that described for the previous experiments.

Results and Discussion

In Experiment 5, a trial was considered an error and was excluded from the RT analysis, if the RT was longer than 1,600 ms or shorter than 250 ms (less than 1% of trials in each of Experiments 5a, 5b, and 5c) or if participants made an incorrect response (8.37% of trials in Experiment 5a, 12.19% of trials in Experiment 5b, and 7.18% of trials in Experiment 5c). Mean RTs and error percentages are presented in Table 7.

In Experiment 5a, there was a main effect of word type that was significant by participants in the RT analysis, $F_s(2, 50) = 9.77$, $p < .01$, $MSE = 1{,}941.74$; $F_i(2, 45) = 2.32$, $p = .11$, $MSE = 4{,}180.60$, and in the error analysis, $F_s(2, 50) = 9.28$, $p < .01$, $MSE = 54.50$; $F_i(2, 45) = 1.08$, $p = .37$, $MSE = 292.38$. Planned

[4] In this second set of relatedness ratings, the mean ratings for the dominantly related mates of the ambiguous words with more related meanings (6.25), the dominantly related mates of the ambiguous words with less related meanings (6.09), and the mates of the unambiguous words (6.15) were, once again, comparable ($F < 1$). The mean relatedness ratings for the subordinately related mates of the ambiguous words with more related meanings (6.01), the subordinately related mates of the ambiguous words with less related meanings (5.55), and the mates of the unambiguous words (6.15) were, in contrast, marginally different, $F(2, 45) = 2.81$, $p = .07$, $MSE = 0.57$. As such, the relatedness may have been slightly weaker for the subordinately related mates of the ambiguous words with less related meanings.

Table 7
Mean Response Times and Error Percentages for Experiment 5 (Relatedness Decision Task)

	RT		Errors		Ambiguity effect		Relatedness effect	
Stimulus type	*M*	*SE*	*M*	*SE*	RT	Errors	RT	Errors
Experiment 5a (with dominantly related mates)								
Ambiguous/less related	702	26.22	19.10	2.09	−47	−6.26	22	8.51
Ambiguous/more related	680	21.25	10.59	1.72	−25	2.25		
Unambiguous	655	22.87	12.84	1.72				
Unrelated filler	695	17.00	2.57	0.66				
Experiment 5b (with subordinately related mates)								
Ambiguous/less related	735	21.32	32.21	2.52	−76	−21.87	52	11.75
Ambiguous/more related	683	16.89	20.46	1.75	−24	−10.12		
Unambiguous	659	18.88	10.34	1.51				
Unrelated filler	704	19.99	3.38	0.67				
Experiment 5c (with unrelated mates)								
Ambiguous/less related	685	21.47	3.64	1.06	0	−0.51	2	1.96
Ambiguous/more related	683	21.69	1.68	0.56	2	1.45		
Unambiguous	685	21.49	3.13	1.11				
Related filler	643	17.66	11.54	1.36				

Note. RT = response time.

comparisons further revealed that response latencies were slower for pairs involving the two types of ambiguous words than for pairs involving unambiguous words. That is, the ambiguity disadvantage for pairs containing the ambiguous words with less related meanings was significant in the RT analysis, $t_s(25) = 3.82$, $p < .01$; $t_i(30) = 2.16$, $p < .05$, and was significant by participants in the error analysis, $t_s(25) = 2.93$, $p < .01$; $t_i < 1$. The ambiguity disadvantage for pairs containing the ambiguous words with more related meanings was significant by participants in the RT analysis, $t_s(25) = 2.77$, $p < .05$; $t_i(30) = 1.13$, $p = .36$, but not in the error analysis, $t_s(25) = 1.12$, $p = .30$; $t_i < 1$. In addition, a significant relatedness advantage was observed. Response latencies were faster for pairs containing ambiguous words with more related meanings than for pairs containing ambiguous words with less related meanings. This effect was significant by participants in the RT analysis, $t_s(25) = 2.14$, $p < .05$; $t_i(30) = 1.04$, $p = .36$, and in the error analysis, $t_s(25) = 4.25$, $p < .01$; $t_i(30) = 1.60$, $p = .11$.

In Experiment 5b, there was a main effect of word type that was significant in the RT analysis, $F_s(2, 50) = 20.45$, $p < .01$, $MSE = 1{,}957.97$; $F_i(2, 45) = 4.46$, $p < .05$, $MSE = 6{,}816.20$, and in the error analysis, $F_s(2, 50) = 39.96$, $p < .01$, $MSE = 77.97$; $F_i(2, 45) = 5.18$, $p < .01$, $MSE = 370.24$. Planned comparisons further revealed that response latencies were slower for pairs containing the two types of ambiguous words than for pairs containing the unambiguous words. That is, the ambiguity disadvantage for pairs containing the ambiguous words with less related meanings was significant in the RT analysis, $t_s(25) = 5.26$, $p < .01$; $t_i(30) = 3.45$, $p < .01$, and in the error analysis, $t_s(25) = 8.00$, $p < .001$; $t_i(30) = 3.31$, $p < .01$. The ambiguity disadvantage for pairs containing the ambiguous words with more related meanings was significant by participants in the RT analysis, $t_s(25) = 2.49$, $p < .05$; $t_i(30) = 1.05$, $p = .38$, and in the error analysis, $t_s(25) = 4.29$, $p < .01$; $t_i(30) = 1.60$, $p = .12$. In addition, a significant relatedness advantage was observed: response latencies were faster for pairs containing ambiguous words with more related meanings than for pairs containing ambiguous words with less related meanings. This effect was significant by participants in the RT analysis, $t_s(25) = 4.41$, $p < .01$; $t_i(30) = 1.71$, $p = .09$, and in the error analysis, $t_s(25) = 5.84$, $p < .01$; $t_i(30) = 1.57$, $p = .12$.[5]

In Experiment 5c, the main effect of word type was not significant in the RT analysis ($F_s < 1$; $F_i < 1$) or in the error analysis, $F_s(2, 50) = 1.15$, $p = .36$, $MSE = 23.18$; $F_i(2, 45) = 1.19$, $p = .35$, $MSE = 13.75$. The lack of a word type effect was probably not due to a lack of power for unrelated trials. Using the *MSE* from unrelated trials, we estimated that, for the unrelated pairs, the power to detect a word type effect of the size observed on related trials was 0.99.

As in Experiments 2 and 3, we ran multiple regression analyses to examine the relationships of target word ambiguity, familiarity (of the second word), relatedness ratings, word frequency (of the second word), and word length (of the second word) to the criterion variables of RT and error rate in Experiment 5. In these analyses, the factor of relatedness of the multiple meanings was not included because this concept does not exist when words with a single meaning are considered (i.e., the unambiguous words). For Experiment 5a, the predictor variables that had significant, unique relationships with RT and errors were ambiguity (to RT only) and word pair relatedness. There was also a relationship of familiarity to errors. For Experiment 5b, the predictor variable that had significant, unique relationships with RT and errors was word pair relatedness. In addition, familiarity was related to RT and fre-

[5] One of the mates used in Experiment 5b was accidentally used twice. We reran these analyses without the data from the word pairs with this word, and the results were unchanged.

quency was related to errors. The direction of the relationship with frequency was positive: more frequent words tended to produce more errors. For Experiment 5c, the only predictor variable that had a significant, unique relationship with RT was word pair relatedness. None of the predictors were related to errors.

The results of Experiment 5 show an ambiguity disadvantage and a relatedness of meanings advantage only on the related ("yes") trials of a relatedness decision task. As in Experiment 3, this was true when word pairs were used in which the mate was related to the dominant meaning of the experimental word or to the subordinate meaning of the experimental word. Experiments 4 and 5 were conducted in Japanese, and the pattern of results was very similar to that produced in Experiments 1 through 3. Although there are obvious script differences between English and Japanese, we found very comparable semantic effects in experiments conducted in the two languages.

The present results also show that when a sequential presentation procedure very similar to that used by Gottlob et al. (1999) is used, the pattern of ambiguity effects does not change. These effects are observed on related trials, however, the same stimuli produce null effects on unrelated trials. The major implication is that these ambiguity effects seem to arise in the relatedness decision-making process and not in the process of meaning activation.

General Discussion

The purpose of this article was to examine the impact of semantic ambiguity on the process of generating meaning from print. According to the basic assumptions of PDP models, semantic ambiguity should slow the process of meaning activation because ambiguous words have one-to-many mappings between orthography and semantics. Indeed, past research had supported that claim (e.g., Gottlob et al., 1999; Hino et al., 2002; Piercey & Joordens, 2000). A null ambiguity effect in the semantic categorization task reported by Forster (1999) and confirmed in our work with narrow semantic categories (Hino et al., 2004), however, prompted us to reconsider this interpretation of the ambiguity disadvantage.

In this article, we investigated the possibility that the ambiguity disadvantage reported in relatedness decision tasks was not produced by the process of meaning activation but was instead produced by a different process, in particular, the decision-making process. In the previous research using relatedness decision tasks, ambiguous words had only been used on related trials, that is, trials on which the meaning(s) of the word that was unrelated to the meaning of its mate might have produced response competition. This competition should not come into play when the ambiguous word appears on unrelated trials (because all meanings are unrelated to the meaning of its mate). Our results for those trials, indeed, show no ambiguity disadvantage (Experiments 2, 3c, and 5c).

Our null ambiguity effect does not appear to be due to poor stimulus selection or inadequate power, because the same stimuli produced a robust ambiguity disadvantage on related trials (Experiments 3a, 3b, 5a, and 5c) and an ambiguity advantage in LDTs (Experiments 1 and 4). In addition, there is converging evidence from other research to rule out the possibility that the null effect of ambiguity observed on unrelated trials could have been due to those trials being insensitive to semantic factors (e.g., Klinger & Greenwald, 1995; Luo et al., 1998). Thus, we conclude that the ambiguity disadvantage reported in relatedness decision tasks is, indeed, not produced by the process of meaning activation.

One issue that should be mentioned concerns the relationship between performance in the relatedness decision task and the lexical decision task. The claim that the meaning activation process is not affected by ambiguity may raise the question of why ambiguity matters in lexical decision. In particular, why are ambiguous words responded to more quickly in lexical decision (Borowsky & Masson, 1996; Hino & Lupker, 1996; Jastrzembski, 1981; Jastrzembski & Stanners, 1975; Kellas, Ferraro, & Simpson, 1988; Millis & Button, 1989; Pexman & Lupker, 1999; Rubenstein, Garfield, & Millikan, 1970)? The answer is that responses in the two tasks rely on different parts of the system. In lexical decision, the response is based primarily on orthographic representations. The activation of orthographic representations occurs more rapidly for ambiguous words due to the additional feedback they receive from the semantic units. In contrast, the relatedness decision task relies exclusively on the semantic representations themselves. Thus, there are no feedback benefits to be had.

Given the results observed in the present experiments, we suggest that the relatedness decision task involves, first, activation of word meanings for the words presented in a pair. This meaning activation process for a word involves activation of an orthographic representation and then a corresponding semantic representation. Second, when the semantic representations have reached a sufficient level of activation, they are compared and assessed for similarity, perhaps in terms of proportion of overlapping or associated features. If they are sufficiently similar, a "yes" response is made; if they are not sufficiently similar, a "no" response is made. This comparison process could be characterized as a random walk or diffusion-type process (e.g., Joordens, Piercey, & Azarbehi, 2003; Ratcliff, 1978) with both a yes (i.e., related) boundary and a no (i.e., unrelated) boundary. The random walk process begins at some point between the two boundaries and, over time, the comparison process drives it towards one boundary or the other depending on the similarity of the two words' meanings. When an ambiguous word is presented on a related trial, there will be less similarity between the two words' semantic representations, which produces a slower drift rate toward the related boundary. The result is slower and more error-prone responses. When an ambiguous word is presented on an unrelated trial, the ambiguity has little effect on the similarity of the two words' semantic representations. (There should be few overlapping features in an unrelated pair, so an additional meaning for the ambiguous word will not change the drift rate in any significant way.) Thus, drift occurs, relatively unhindered, to the unrelated boundary.

By this account, if semantic activation can occur relatively quickly for a particular type of word (e.g., if word meaning is primed, as in the Klinger & Greenwald, 1995, study) then the decision process can begin relatively quickly and an overall processing advantage should be observed for that type of word. Similarly, if semantic activation is relatively slow for a particular type of word (as, according to PDP models, should be true for ambiguous words), then the start of the decision process would be somewhat delayed. Thus, the decision process should not mask semantic processing differences.

In Experiments 4 and 5, we also examined the effect of relatedness of meanings for ambiguous words. Relatedness of meanings did not influence LDT performance or performance on unrelated trials in the relatedness decision task. It was only on related trials that we observed any effect of relatedness of meanings. In particular, there was a relatedness advantage: Responses were faster for ambiguous words with more related meanings than for ambiguous words with less related meanings. The fact that the relatedness of meaning advantage was observed only on related trials suggests that, like the ambiguity disadvantage, the relatedness advantage does not arise during the meaning activation process but, instead, is a decision-making effect. Also, the null effect of relatedness of meaning on unrelated trials seems to support Klein and Murphy's (2001, 2002) assertion that different meanings (and different senses) are represented separately in the semantic system, whether related or not.

On the issue of how relatedness influences the decision-making process on positive trials in the relatedness decision task, one could argue that, for words with related meanings, the different meanings share features (or have associated features) and, thus, there is less evidence that the word is unrelated to its mate. That is, the ambiguity disadvantage in the decision-making process for "yes" responses for pairs such as *bat–vampire* is produced by evidence for unrelatedness that comes from the baseball meaning of *bat*. When the ambiguous word's multiple meanings are somewhat more related (e.g., *home–family*), the additional meanings (of *home*) have fewer features that are unrelated to the meaning of the paired word. Thus, in terms of the random walk account we have described, ambiguous words with more related meanings should produce faster drift toward the related boundary (less erroneous drift toward the unrelated boundary) than ambiguous words with less related meanings.

For ambiguous words, the drift rate toward the related boundary may be somewhat slower when the mate is a word related to the subordinate meaning (i.e., Experiments 3b and 5b). Presumably, the dominant meaning has a higher level of activation than the subordinate meaning. When these subordinate-meaning pairs are used, it is the dominant meaning of the ambiguous words that is unrelated to its mate. Thus, the evidence for unrelatedness would be somewhat stronger in Experiments 3b and 5b than in Experiments 3a and 5a in which the subordinate meaning is the meaning that is unrelated to the other word in the pair. Thus, the cost for these pairs should be larger than in Experiments 3a and 5a, as was observed.

The conclusion that the process of meaning activation is not slowed by semantic ambiguity runs counter to the claims made by Gottlob et al. (1999) and Piercey and Joordens (2000). In considering whether there is a way for a PDP-type model to explain this result, we evaluated the impact of dropping the assumption that, in the relatedness decision task, it is necessary for the semantic system to reach a stable state. As noted by Piercey and Joordens (2000), PDP models first represent the meaning of ambiguous words as a blend of both meanings. Because this blend state contains features of both meanings, Piercey and Joordens assumed that it would be a sufficient basis for LDT performance but not for relatedness decision task performance. What would be the implication for PDP models if we dropped this assumption and assumed instead that accurate relatedness decisions could also be made on the basis of a blend state?

As Hinton and Shallice (1991) have argued, the geometry of high-dimensional semantic space used in simulations of PDP models produces representations such that visually similar words tend to be represented as nearby points in semantic space, even though the meanings of the words are very different (see, in particular, Appendix A in Hinton & Shallice, 1991). A semantically ambiguous word like *bat* is clearly a strong version of this situation. The two meanings correspond to identical visual patterns and, hence, should be represented close to each other in semantic space. The semantic blend state for *bat* would then fall somewhere between these two close regions in semantic space.

On related trials in the relatedness decision task, participants are asked to decide whether *bat* and *vampire* are related. Because the mammal meaning of *bat* and the meaning of *vampire* are related, those meanings should be represented relatively closely in semantic space. If *bat* is initially represented by a blend state, then this blended representation for *bat* will actually be further from the representation for *vampire* in semantic space than the representation for the mammal *bat* would be. This additional distance in semantic space could slow related responses for pairs like *bat–vampire* (as opposed to pairs of unambiguous words), as we observed in our experiments. However, the closeness of the blend state for *bat* to the semantic representation for *vampire* could allow for accurate, if slower, responding. In contrast, unrelatedness judgments ("no" responses) would not be slowed for ambiguous word pairs (e.g., *seal–jury*) relative to unambiguous word pairs, because all of the features of both words are unrelated and the representations for the meanings of the words in semantic space are very distant, whether the words are ambiguous or not.[6]

This blend state explanation would also seem to explain the relatedness of meaning advantage observed on related trials in Experiment 5. For ambiguous words with more related meanings (e.g., *home*), the meanings would be closer in semantic space than for ambiguous words with less related meanings (e.g., *bat*). Consequently, the blend state for an ambiguous word with more related meanings (*home*) would be expected to be closer to the paired related word (e.g., *family*) than would the blend state for ambiguous words with less related meanings. This should result in a smaller ambiguity disadvantage on related trials for ambiguous words with more related meanings, as was observed.

If one is willing to accept the assumption that the relatedness decision task could be performed based on the blend state, then this explanation, which is grounded in the geometry of high-dimensional semantic space, could allow PDP models to account for our results. One problem with this account, however, is that it does not explain why there is an ambiguity disadvantage on "no" (nonexemplar) trials in broad or difficult semantic categorization tasks (Hino et al., 2002; Hino et al., 2004). That is, in these experiments, participants were slower to decide that ambiguous words such as *bank* do not represent living things (in comparison to unambiguous words), but they were not slower to decide that *bank* is not a vegetable (in comparison to unambiguous words). In neither case (neither the living thing nor the vegetable decision) was the target related to the category, so the representation for *bank* should be distant from, and clearly not a member of, both categories in semantic space. The fact that an ambiguity disadvantage is observed for nonexemplars when we used the living thing

[6] Thanks to David Plaut for raising this possibility and discussing it with us.

category but not the vegetable (or animal) category suggests that the effect arises because of the way decisions are made about ambiguous words, not because of the way meanings are activated for ambiguous words. As such, a decision-based explanation would still appear to be the most parsimonious explanation of ambiguity effects in both the semantic categorization task and the relatedness decision task.

An alternative interpretation of our results could be derived based on a system of local representations. That is, each word meaning could be represented separately, rather than across a single set of semantic units. Activation could accumulate in the local semantic representations independently, rather than having the distributed representations for the meanings of an ambiguous word compete for activation across the same set of units. Page (2000) and Bowers (2002) have made compelling arguments about the potential of localist accounts to explain a wide range of phenomena.

Another possibility would be to adopt the controversial idea that there might be multiple subsets of semantic units rather than a single set of semantic units. As a result, the different meanings of an ambiguous word could be represented in separate subsets of distributed semantic units. For instance, the mammal *bat* could be represented across one set of units and the baseball *bat* could be represented across another. With this assumption, spelling–meaning inconsistency would be minimal even for ambiguous words. Consequently, the speed of meaning activation would be similar regardless of a word's number of meanings.

The possibility that different meanings of an ambiguous word are represented separately gains some support from findings reported by H. Damasio and colleagues. Based on brain imaging studies, and also on studies involving patients with category-specific semantic deficits, these researchers reported that different neural regions are associated with retrieval of different types of semantic information (for contrasting views, however, see, e.g., Devlin, Gonnerman, Andersen, & Seidenberg, 1998; Tyler & Moss, 2001; Tyler, Moss, Durrant-Peatfield, & Levy, 2000). Semantic processing of words that denote concrete entities (nouns) was localized to higher order association cortices in the left temporal region, whereas semantic processing of words that denote actions (verbs) was localized to left prefrontal and premotor regions (H. Damasio, 2001; Tranel, Damasio, & Damasio, 1998). Further, additional studies showed that semantic processing of different categories of concrete entities (e.g., persons, tools, living things) was localized to partially segregated neural systems (Tranel, Damasio, & Damasio, 1997; Damasio, Grabowski, Tranel, Hichwa, & Damasio, 1996). These results suggest that, to the extent that the meanings of ambiguous words tend to fall into different categories, the different meanings could be represented separately (although they say nothing about whether these representations are best thought of as localist or separate sets of distributed units). There is some neuropsychological support for this separate subsets account of semantic representation, but several aspects of processing in this type of model are unspecified. For instance, it is unclear how the system allocates concepts to the different subsets. One possibility is that they could be allocated by the type of features involved in representation. Certainly, additional research is required.

Conclusion

The results of our experiments suggest that semantic ambiguity does not affect the speed of meaning activation for printed words presented without context. Rather, they suggest that ambiguity effects in relatedness decision tasks are due to the decision-making process. Thus, these results provide additional data with which to constrain theories of semantic representation.

References

Azuma, T., & Van Orden, G. C. (1997). Why SAFE is better than FAST: The relatedness of a word's meanings affects lexical decision times. *Journal of Memory and Language, 36,* 484–504.

Balota, D. A., Ferraro, R. F., & Connor, L. T. (1991). On the early influence of meaning in word recognition: A review of the literature. In P. J. Schwanenflugel (Ed.), *The psychology of word meanings* (pp. 187–221). Hillsdale, NJ: Erlbaum.

Balota, D. A., & Paul, S. T. (1996). Summation of activation: Evidence from multiple primes that converge and diverge within semantic memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22,* 827–845.

Balota, D. A., Paul, S. T., & Spieler, D. H. (1999). Attentional control of lexical processing pathways during word recognition and reading. In S. C. Garrod & M. J. Pickering (Eds.), *Language processing* (pp. 15–57). Hove, England: Psychology Press.

Besner, D., & Joordens, S. (1995). Wrestling with ambiguity—Further reflections: Reply to Masson and Borowsky (1995) and Rueckl (1995). *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 515–519.

Borowsky, R., & Besner, D. (1993). Visual word recognition: A multistage activation model. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19,* 813–840.

Borowsky, R., & Masson, M. E. J. (1996). Semantic ambiguity effects in word identification. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22,* 63–85.

Bowers, J. S. (2002). Challenging the widespread assumption that connectionism and distributed representations go hand-in-hand. *Cognitive Psychology, 45,* 413–445.

Cohen, J. D., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: An interactive graphic system for designing and controlling experiments in the psychology laboratory using Macintosh computers. *Behavior Research Methods, Instruments, & Computers, 25,* 257–271.

Coltheart, M., Davelaar, E., Jonasson, J. T., & Besner, D. (1977). Access to the internal lexicon. In S. Dornic (Ed.), *Attention and performance VI* (pp. 535–555). New York: Academic Press.

Damasio, H. (2001). Words and concepts in the brain. In J. Branquinho (Ed.), *The foundations of cognitive science* (pp. 109–120). Oxford, UK: Oxford University Press.

Damasio, H., Grabowski, T. J., Tranel, D., Hichwa, R. D., & Damasio, A. (1996). A neural basis for lexical retrieval. *Nature, 380,* 499–505.

Devlin, J. T., Gonnerman, L. M., Andersen, E. S., & Seidenberg, M. S. (1998). Category-specific semantic deficits in focal and widespread brain damage: A computational account. *Journal of Cognitive Neuroscience, 10,* 77–94.

Duffy, S. A., Morris, R. K., & Rayner, K. (1988). Lexical ambiguity and fixation times in reading. *Journal of Memory and Language, 27,* 429–446.

Forster, K. I. (1999, November). *Beyond lexical decision: Lexical access in categorization tasks.* Paper presented at the 40th Annual Meeting of the Psychonomic Society, Los Angeles, CA.

Gottlob, L. R., Goldinger, S. D., Stone, G. O., & Van Orden, G. C. (1999). Reading homographs: Orthographic, phonologic, and semantic dynamics. *Journal of Experimental Psychology: Human Perception and Performance, 25,* 561–574.

Hino, Y., & Lupker, S. J. (1996). Effects of polysemy in lexical decision and naming: An alternative to lexical access accounts. *Journal of Experimental Psychology: Human Perception and Performance, 22,* 1331–1356.

Hino, Y., Lupker, S. J., & Pexman, P. M. (2002). Ambiguity and synonymy effects in lexical decision, naming, and semantic categorization tasks: Interactions between orthography, phonology, and semantics. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28,* 686–713.

Hino, Y., Pexman, P. M., & Lupker, S. J. (2004). *Effects of ambiguity and relatedness of meanings in lexical decision and semantic categorization tasks: Is the speed of semantic coding modulated by the nature of orthographic-to-semantic mappings*? Manuscript submitted for publication.

Hinton, G. E., & Shallice, T. (1991). Lesioning an attractor network: Investigations of acquired dyslexia. *Psychological Review, 98,* 74–95.

Jastrzembski, J. E. (1981). Multiple meanings, number of related meanings, frequency of occurrence, and the lexicon. *Cognitive Psychology, 13,* 278–305.

Jastrzembski, J. E., & Stanners, R. F. (1975). Multiple word meanings and lexical search speed. *Journal of Verbal Learning and Verbal Behavior, 14,* 534–537.

Joordens, S., & Besner, D. (1994). When banking on meaning is not (yet) money in the bank: Explorations in connectionist modeling. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20,* 1051–1062.

Joordens, S., Piercey, C. D., & Azerbehi, R. (2003, April). *From word recognition to lexical decision: A random walk along the road of harmony.* Paper presented at the 5th International Conference on Cognitive Modeling, Bamberg, Germany.

Kawamoto, A. H., Farrar, W. T., & Kello, C. T. (1994). When two meanings are better than one: Modeling the ambiguity advantage using a recurrent distributed network. *Journal of Experimental Psychology: Human Perception and Performance, 20,* 1233–1247.

Kellas, G., Ferraro, F. R., & Simpson, G. B. (1988). Lexical ambiguity and the timecourse of attentional allocation in word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 14,* 601–609.

Klein, D. E., & Murphy, G. L. (2001). The representation of polysemous words. *Journal of Memory and Language, 45,* 259–282.

Klein, D. E., & Murphy, G. L. (2002). Paper has been my ruin: Conceptual relations of polysemous senses. *Journal of Memory and Language, 47,* 548–570.

Klinger, M. R., & Greenwald, A. G. (1995). Unconscious priming of association judgments. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 569–581.

Kučera, H., & Francis, W. (1967). *Computational analysis of present-day American English.* Providence, RI: Brown University Press.

Luo, C. R., Johnson, R. A., & Gallo, D. A. (1998). Automatic activation of phonological information in reading: Evidence from the semantic relatedness decision task. *Memory & Cognition, 26,* 833–843.

Lupker, S. J. (1984). Semantic priming without association: A second look. *Journal of Verbal Learning and Verbal Behavior, 23,* 709–733.

Masson, M. E. J. (1991). A distributed memory model of context effects in word identification. In D. Besner & G. W. Humphreys (Eds.), *Basic processes in reading: Visual word recognition* (pp. 233–263). Mahwah, NJ: Erlbaum.

Millis, M. L., & Button, S. B. (1989). The effect of polysemy on lexical decision time: Now you see it, now you don't. *Memory & Cognition, 17,* 141–147.

National Language Research Institute. (1993). *Bunrui Goi Hyou (floppy disk version)* [Thesaurus (floppy disk version)]. Tokyo: Shuei Shuppan.

Page, M. (2000). Connectionist modeling in psychology: A localist manifesto. *Behavioral and Brain Sciences*, *23*, 443–512.

Pecher, D. (2001). Perception is a two-way junction: Feedback semantics in word recognition. *Psychonomic Bulletin & Review, 8,* 545–551.

Pexman, P. M., & Lupker, S. J. (1999). Ambiguity and visual word recognition: Can feedback explain both homophone and polysemy effects? *Canadian Journal of Experimental Psychology, 53,* 323–334.

Piercey, C. D., & Joordens, S. (2000). Turning an advantage into a disadvantage: Ambiguity effects in lexical decision versus reading tasks. *Memory & Cognition, 28,* 657–666.

Plaut, D. C., McClelland, J. L., Seidenberg, M. S., & Patterson, K. (1996). Understanding normal and impaired word reading: Computational principles in quasi-regular domains. *Psychological Review, 103,* 56–115.

Plaut, D. C., & Shallice, T. (1993). Deep dyslexia: A case study of connectionist neuropsychology. *Cognitive Neuropsychology, 10,* 377–500.

Pugh, K. R., Rexer, K., & Katz, L. (1994). Evidence of flexible coding in visual word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 20,* 807–825.

Ratcliff, R. (1978). A theory of memory retrieval. *Psychological Review, 85,* 59–108.

Rayner, K., & Duffy, S. A. (1986). Lexical complexity and fixation times in reading: Effects of word frequency, verb complexity, and lexical ambiguity. *Memory & Cognition, 14,* 191–201.

Rodd, J., Gaskell, G., & Marslen-Wilson, W. (2002). Making sense of semantic ambiguity: Semantic competition in lexical access. *Journal of Memory and Language, 46,* 245–266.

Rubenstein, H., Garfield, L., & Millikan, J. A. (1970). Homographic entries in the internal lexicon. *Journal of Verbal Learning and Verbal Behavior, 9,* 487–494.

Rueckl, J. G. (1995). Ambiguity and connectionist networks: Still settling into a solution—Comment on Joordens and Besner (1994). *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 501–508.

Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of word recognition and naming. *Psychological Review, 96,* 523–568.

Stone, G. O., Vanhoy, M., & Van Orden, G. C. (1997). Perception is a two-way street: Feedforward and feedback phonology in visual word recognition. *Journal of Memory and Language, 36,* 337–359.

Tranel, D., Damasio, H., & Damasio, A. (1997). A neural basis for the retrieval of conceptual knowledge. *Neuropsychologia, 35,* 1319–1327.

Tranel, D., Damasio, H., & Damasio, A. (1998). The neural basis of lexical retrieval. In R. W. Parks, D. S. Levine, et al. (Eds.), *Fundamentals of neural network modeling: Neuropsychology and cognitive neuroscience* (pp. 271–296). Cambridge, MA: The MIT Press.

Tyler, L. K., & Moss, H. E. (2001). Towards a distributed account of conceptual knowledge. *Trends in Cognitive Sciences, 5,* 244–252.

Tyler, L. K., Moss, H. E., Durrant-Peatfield, M. R., & Levy, J. P. (2000). Conceptual structure and the structure of concepts: A distributed account of category-specific deficits. *Brain and Language, 75,* 195–231.

Umesao, T., Kindaichi, H., Sakakura, A., & Hinohara, S. (1995). *Nihongo dai-jiten: Dai2-ban* [The great Japanese dictionary: second edition]. Tokyo: Kodansha.

Van Orden, G. C., & Goldinger, S. D. (1994). The interdependence of form and function in cognitive systems explains perception of printed words. *Journal of Experimental Psychology: Human Perception and Performance, 20,* 1269–1291.

Wike, E. L., & Church, J. D. (1976). Comments on Clark's "The language-as-fixed-effects fallacy." *Journal of Verbal Learning and Verbal Behavior, 15,* 249–255.

(*Appendixes follow*)

Appendix A

Word Stimuli Used in Experiments 1 and 2

LF ambig	Unrelated mate	LF unambig	Unrelated mate	HF ambig	Unrelated mate	HF unambig	Unrelated mate
Unrelated word pairs ("no" responses)							
rash	found	**evade**	soup	**well**	clown	**event**	copper
punch	short	**cove**	year	**shot**	rice	**food**	reef
hail	dune	**badge**	smooth	**watch**	brain	**green**	baseball
spade	never	**sewer**	over	**fine**	devil	**half**	couch
shed	fact	**dagger**	sky	**march**	fraud	**lack**	boat
seal	jury	**deaf**	velvet	**miss**	cobra	**lady**	mist
lean	spider	**lung**	child	**pass**	harpoon	**loss**	photo
pupil	hawk	**lamp**	pie	**date**	blood	**news**	salt
beam	sheep	**tent**	minnow	**post**	foam	**nine**	jump
sink	teacher	**solve**	tulip	**order**	bird	**often**	carry
draft	quiet	**gang**	jazz	**club**	old	**paid**	sickness
purse	van	**beard**	canyon	**range**	once	**river**	crowd
bark	fox	**brawl**	sofa	**fall**	jail	**small**	music
ruler	rabbit	**trout**	people	**spring**	cork	**woman**	lunch
calf	school	**chef**	bed	**letter**	cloud	**street**	sand
Ambig	Related unambig mate	Ambig	Related unambig mate	Unambig	Related unambig mate	Unambig	Related unambig mate
Related word pairs ("yes" responses)							
tie	shirt	suit	vest	white	black	cottage	house
fork	knife	coat	hat	truck	car	wager	gamble
iron	steel	can	able	tomato	lettuce	hill	mountain
shrink	grow	nurse	doctor	cotton	wool	chocolate	vanilla
firm	soft	file	folder	cat	dog	potato	yam
kind	nice	stick	stone	lion	tiger	glove	mitten
may	june	band	elastic	gold	silver	pig	cow
lie	cheat	nut	acorn	roof	floor	moth	butterfly
wake	sleep	skip	spin	gun	pistol	carrot	pea
sock	shoe	saw	drill	snow	sleet	mule	donkey
table	chair	trunk	suitcase	butter	bread	thread	string
orange	apple	bill	dollar	queen	king	turkey	chicken
pine	oak	straw	hay	sailor	soldier	herb	spice
second	third	kid	lamb	scared	afraid	weed	grass
organ	piano	toast	muffin	lime	lemon	ketchup	mustard

Note. The words presented in Experiment 1 (critical words) are in bold. Order of words in each pair was varied between subjects. LF = low frequency; HF = high frequency; Ambig = ambiguous; Unambig = unambiguous.

Appendix B

Word Stimuli Used in Experiment 3

Target word	Experiment 3a: dominantly related pair word	Experiment 3b: subordinately related pair word	Experiment 3c: unrelated pair word
Ambiguous target word pairings			
bat	baseball	vampire	water
charge	credit	battery	basin
draft	army	beer	piano
hide	conceal	skin	glass
firm	solid	company	summer
mug	glass	rob	credit
organ	piano	heart	solid
pack	suitcase	wolf	tumble
ring	finger	bell	gulp
roll	tumble	bread	star
sink	basin	descend	finger
spring	summer	coil	peso
swallow	gulp	bird	army
well	water	fine	baseball
Unambiguous target word pairings			
oak	wood	wood	fight
corner	edge	edge	goat
sheep	goat	goat	edge
car	truck	truck	peak
sky	cloud	cloud	truck
brawl	fight	fight	suitcase
soup	food	food	wood
neck	waist	waist	conceal
dollar	peso	peso	cloud
mountain	peak	peak	orange
square	shape	shape	pause
sun	star	star	waist
apple	orange	orange	shape
stop	pause	pause	food
Filler word pairings			
second	black	black	third
suit	stone	stone	vest
coat	lettuce	lettuce	hat
can	floor	floor	able
nurse	sleet	sleet	doctor
file	muffin	muffin	folder
stick	lemon	lemon	stone
band	bread	bread	elastic
nut	hat	hat	acorn
skip	afraid	afraid	spin
saw	spin	spin	drill
straw	third	third	hay
kid	folder	folder	lamb
toast	wool	wool	muffin
white	drill	drill	black
tomato	able	able	lettuce
cotton	king	king	wool
cat	vest	vest	dog
lion	silver	silver	tiger
gold	elastic	elastic	silver
roof	soldier	soldier	floor
gun	acorn	acorn	pistol
snow	pistol	pistol	sleet
butter	tiger	tiger	bread
queen	dog	dog	king
sailor	lamb	lamb	soldier
scared	hay	hay	afraid
lime	doctor	doctor	lemon

Note. The critical words presented in Experiment 3 are in bold.

(*Appendixes continue*)

Appendix C

Word Stimuli Used in Experiments 4 and 5 and Their English Translations

Dominant prime		Subordinate prime		Target	
		Ambiguous words with less related meanings			
ジャケット	jacket	テニス	tennis	コート	coat/court
金具	metal fittings	レシーブ	receive	スパイク	spike
マーケット	market	超越	going over	スーパー	super
特性	property	ワープロ	word processor	タイプ	type
調査	investigation	模様	pattern	チェック	check
船	ship	レコーダー	recorder	デッキ	deck
貨物	freight	陸上	athletics	トラック	truck/track
見どころ	good points	タバコ	cigarette	ハイライト	highlight/a name of a cigarette
住宅	house	食品	food	ハウス	house/a name of a food company
スポーツ	sport	掘削	excavation	ボーリング	bowling boring
手紙	letter	地位	position	ポスト	post
奇術	trick	ペン	pen	マジック	magic
包装	packing	音楽	music	ラップ	wrap
テープ	tape	漫画	cartoon	リボン	ribbon/a name of a cartoon magazine
宝石	jewel	ホラー	horror	リング	ring/a name of a horror movie
無駄	useless	アメリカ	America	ロス	loss/Los Angeles
		Ambiguous words with more related meanings			
野球	baseball	外側	outside	アウト	out
写真	photograph	音楽	music	アルバム	album
茶碗	bowl	賞杯	prize cup	カップ	cup
覆い	cover	フォロー	follow	カバー	cover
メガネ	glasses	接触	touch	コンタクト	contact
名前	name	合図	signal	サイン	sign
一式	one set	組立て	assemble	セット	set
穏やか	calm	球技	ball game	ソフト	soft
サッカー	soccer	トランプ	cards	パス	pass
歌謡曲	popular song	本塁打	home run	ヒット	hit
橋	bridge	体操	gymnastics	ブリッジ	bridge
皿	dish	板	board	プレート	plate
コンクリー	concrete	アタック	attack	ブロック	block
重要	important	得点	score	ポイント	point
家族	family	ベース	base	ホーム	home
四角	square	ステップ	step	ボックス	box

Prime		Target	
	Unambiguous words		
疑問	question	アイデア	idea
じゅうたん	carpet	カーペット	carpet
年賀	New Year's greetings	ギフト	gift
ヒント	hint	クイズ	quiz
費用	expense	コスト	cost
草履	Japanese sandals	サンダル	sandals
季節	season	シーズン	season
ジョギング	jog	シューズ	shoe
スカート	skirt	ズボン	pants
塔	tower	タワー	tower
自転車	bicycle	バイク	bike
テキスト	text	ブック	book
予定	plan	プラン	plan
公園	park	ベンチ	bench
給料	salary	ボーナス	bonus
やかん	kettle	ポット	pot

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