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Semantic Representations of Word Meanings by the Cerebral Hemispheres

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Two priming experiments investigated kind and strength of semantic knowledge underlying known, frontier, and unknown low frequency words. Results from Experiment 1 suggest that known words reflect categorical knowledge, but frontier and unknown words reflect thematic knowledge. Thematic knowledge for frontier words appears to be stronger than that for unknown words. Experiment 2 entailed visual half-field presentation of targets. All facilitory effects were restricted to the lvf/RH, and inhibitory effects to the rvf/LH. Experiment 1 findings were mirrored by the RH. Thematic knowledge appears to precede categorical knowledge for the RH, but the opposite may be true of the LH . Results are also discussed in terms of the RH role in meaning acquisition and metacontrol.

Key Words: word knowledge; partial knowledge; hemisphere(s); laterality; cerebral asymmetry; word meaning; meaning acquisition; metacontrol; priming; semantic representation(s); low frequency words.

INTRODUCTION

Two experiments were conducted to explore the kinds of semantic knowledge at different levels of word knowledge, and how this knowledge may be organized and differentially processed by the cerebral hemispheres. The first experiment investigated the semantic processing of words at different levels of knowledge, and the second experiment examined the role each cerebral hemisphere plays in the processing of these words.

The acquisition of word meanings can be viewed as a process in which underlying semantic knowledge exists at different levels (Loewenthal, 1971; Shore & Kempe,1999; Trembly, 1966). Durso and Shore (1991; Shore & Durso, 1990) investigated known, frontier, and unknown levels of word knowledge. Words that the participant correctly defined or used in a novel sentence were considered to be at the known level. Words indicated to be familiar in the absence of the ability to define, write a synonym for, or use the word in a novel sentence were considered frontier words.

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Words that participants incorrectly believed to be nonwords (pronounceable fabrications) were considered to be at the unknown level.

Interestingly, when presented with pairs of sentences in which one sentence used the known, frontier, or unknown word correctly and the false sentence violated general definitional constraints participants chose the correct sentence for all three levels with a probability significantly higher than chance. When the false sentences violated specific definitional details, or when simple correct–incorrect decisions about isolated sentences were required, participants performed above chance for known and frontier words only (Durso & Shore, 1991, Experiments 1 and 4). The possibility that the above-chance performance for unknown or frontier words resulted from methodological errors (such as systematic differences in the quality of the correct and false sentences, or the additional cues of context not present during initial word level assessment) was eliminated (Durso & Shore, 1991, Experiments 2 and 3). Additionally, free associations to unknown and frontier words proved to be relevant to their meanings, despite the participants' belief that these free associations were irrelevant (Durso & Shore, 1991, Experiment 6; Shore, Rea, & Kovach, 2000).

One important implication of Durso and Shore's research is the existence of semantic knowledge for frontier and unknown words despite the participants belief that they do not possess this knowledge and that they cannot (or will not) access this knowledge. This is further supported by faster response times to known words than frontier, and to frontier words than unknown (Shore, 1994). Generally, as knowledge increases (due to exposure or repetition) response times decrease (e.g., Bradshaw & Anderson, 1982; Pirolli & Anderson, 1985; Lewellen, Goldinger, Pisoni, & Greene, 1993). At the least, participants have knowledge about frontier and unknown words that enable recognition of appropriate usage, but seem to be explicitly unaware of the existence of their own semantic knowledge, and unable to recall a definition.

A second implication is that known, frontier, and unknown words seem to reflect different semantic representations. It is clear that known word knowledge consists of explicit, specific definitional knowledge, and also knowledge of general definitional constraints. (Whether these kinds of knowledge are independently represented or one kind is emergent from or inferred from another kind was not investigated by Shore and colleagues, and is not currently clear.) Interestingly, performance with frontier words on the sentence decision tasks indicates that frontier knowledge may not be much different from that for known words. However, these word levels are indeed different in that participants have a higher probability of correct sentences for known than frontier, and semantic knowledge for known words is recalled and frontier semantic knowledge is not. Most peculiar is the inability to access frontier semantic knowledge (definitions) while being simultaneously able to access lexical knowledge (familiarity). Ability to access lexical knowledge may be necessary but insufficient for access to semantic knowledge, and the existence of specific definitional knowledge at the frontier level seems to be insufficient to enable explicit recall of this knowledge. In fact, while the research of Shore and colleagues implies that known and frontier word knowledge is seemingly similar their research precludes an understanding of why known and frontier words are treated differently by participants.

Unknown word knowledge seems to be similar to frontier and known word knowledge with respect to general definitional constraints, but poor performance on definitional constraint sentence decisions suggests that unknown word knowledge may be minimal and broad-based. Perhaps, some specific definitional knowledge (explicit at the known level, implicit at the frontier level) is a necessary condition of, at least, familiarity. While there exists semantic knowledge for unknown words, it may not be the kind that enables familiarity.

The goal of the first experiment reported here was to determine why participants recall meanings for known but not frontier words, and why frontier words are familiar but unknown words are unfamiliar. Why are these words treated differently by participants? What is different about them? Specifically, it was hypothesized that there are differences in the kind and/or strength of the underlying semantic representations. Two possibilities were investigated. One possibility is simply that there are quantitative differences in the underlying strength of the semantic knowledge and a certain ‘‘quantity threshold’’ must be reached for explicit access. In a series of experiments, Dagenbach, Carr, and Barnhardt (1990) have demonstrated that the amount/strength of semantic knowledge influences accessibility to such knowledge. After one reading of the definitions of unfamiliar words participants who subsequently recognized but did not recall the definition responded to related words more slowly than to unrelated words (‘‘inhibition’’). However, after two readings of the definitions, participants who were able to recognize but not recall the definitions responded equally fast to related and unrelated words. Those participants who studied the definitions twice and were subsequently able to recall the definition responded more quickly to related words than unrelated words (‘‘facilitation’’).

Dagenbach et al. (1990) argue that the inhibition observed for words that were studied once and subsequently recognized is a reflection of a weak semantic representation. There was simply not enough information extracted from one study session to provide a strong underlying semantic representation. The weakening of inhibition or trend toward facilitation for words that were studied twice and recognized reflects a strengthening of that representation. Similarly, clear facilitation for words that were studied twice and whose definitions could be recalled is an indication of a strong semantic representation. Strength of representation is typically viewed to reflect ease of accessibility. Because the quality of the definition remained constant for each study session, it is difficult to argue that participants were acquiring different kinds of semantic information each time they studied the definition. Rather, the increase in knowledge is likely to be a quantitative increase in the strength of the underlying representation due to repeated exposure.

Although Dagenbach et al. (1990) did not control for known, frontier, and unknown levels, their research does suggest that different amounts of knowledge result in behavioral differences that parallel those observed with known and frontier words (they discarded words whose definitions were not recognized). Words whose definitions can be recalled reflect stronger semantic representations (more knowledge) than words whose definitions are only recognized. It is not known if participants would recognize definitions of frontier words, but it seems plausible given that they can provide meaningful associations (e.g., Shore et al., 2000). Thus, it may be that known words simply have stronger semantic representations than frontier words. Similarly, words may be unfamiliar (i.e., unknown) to participants because the underlying representation is simply too weak to enable familiarity. The existence of three word levels may reflect two quantity or strength thresholds, one for familiarity, and one for definitional access. As word knowledge increases, the strength of the underlying semantic representation also increases.

A second possible reason for differences between known, frontier, and unknown words is that the semantic knowledge is qualitatively different. Semantic knowledge may be synonyms (e.g., home–house), superordinate categories (e.g., home–building) (e.g., Battig & Montague, 1969; Hunt & Hodge, 1971), an attribute or perceptual feature (e.g., home–warm) (e.g., Flores d’Arcais, Schreuder, & Glanzenborg, 1985; Schreuder, Flores d’Arcaise, & Glanzenborg, 1984), an associated/context-related word (e.g., home–family) (e.g., Chaffin, 1997; Fischler, 1977), and/or a member in the same category (e.g., home–shanty) (e.g., Chaffin, 1997; Fischler, 1977; Lupker, 1984), to name a few. The knowledge underlying known, frontier, and unknown words may differentially conform to one or more of these kinds of knowledge.

Chaffin (1997) segregated the types of associations people make to nouns that are highly familiar (e.g., axe) and weakly familiar or unfamiliar (e.g., awl) and found that the type of associations adults generate to highly familiar words are different from those words that are ranked as low-familiarity. Participants wrote more thematic associations to highly familiar words (e.g., tailor: suit; two nouns that appear in the same context but are not members of the same category), and more categorical (e.g., robin: bird; one word is a category and the other is an exemplar of that category) and coordinate associations (e.g., tiger: lion; two exemplars of the same category) to low familiarity words. Chaffin's research suggests that detailed, specific contextual constraints of a word are more readily available for highly familiar words, but broad, categorical knowledge is more readily available for words that are low in familiarity. Chaffin (1997) argues that adults, much like preschool children (e.g., Markman & Hutchinson, 1984; Markman & Wachtel, 1988; Waxman & Gelman, 1986; for review see Markman, 1989), are attempting to equate the vaguely familiar or unfamiliar word with a highly familiar word. Because highly familiar words are well known, their definitions or synonyms may not be automatically brought to mind. Rather, contextual associates or characteristics become the most prominent associations.

Following the reasoning of Chaffin (1997), known word definitions may be explicitly available due to a reliance on, or the acquisition of, thematic knowledge (contextual associates). Frontier and unknown word meanings may be unavailable due to primary reliance on category-based knowledge (category to which the low frequency word belongs or other words that are members of the same category) and a lack of acquired thematic knowledge. The likely implication for the acquisition of word meanings is that broad categorical knowledge is acquired first, perhaps minimal amounts at the unknown level, with subsequent additions of thematic associates as knowledge progresses to frontier and known levels. In this sense, the acquisition of thematic knowledge is a necessary condition for explicit definition retrieval. However, to argue that both frontier and unknown words reflect reliance on categorical knowledge now provides us with the question of why frontier words are familiar and unknown words are not.

At present, it is not known if these three levels of word knowledge are nested levels or truly independent of each other. If they are nested levels, then the semantic knowledge underlying unknown words would also be present at the frontier level, and the knowledge at the frontier level would also be present at the known level. The differences between the levels may be the addition of new kinds of information (qualitative) and the strengthening of existing information (quantitative). Intuitively, the overlapping similarities between known, frontier, and unknown words suggest that the former is more plausible, and accessibility to the underlying information is determined by both strength and kind of the semantic representation. Based on the work of Chaffin (1997), it could be predicted that unknown words reflect weak semantic representations of categorical knowledge, frontier words reflect stronger semantic representations of categorical knowledge and, perhaps, weak representations of thematic knowledge, and known words reflect strong representations of both categorical and thematic knowledge. If the word levels are nested and reflect the process of meaning acquisition, then categorical information may be acquired first, followed by thematic information. However, there is reason to believe that the opposite is true, in that thematic information would be acquired prior to, or perhaps simultaneously with, categorical information.

Landauer and Dumais (1997) liken the acquisition of meaning to a process of assimilating words into a frequency of cooccurrence matrix. They suggest that words become semantically related by the contexts in which they concurrently appear. It is here that an interesting paradox arises. Unless preliminary contexts are very specific, an individual may find it very difficult to equate the word with something they know well, and immediately learn the category to which a word belongs or know what other objects are members of the same category. That is, specific category-based knowledge may not be obvious from the context.

It is more likely that novel words would become associated with words appearing in the same context, that is, thematic associates. An unlikely sentence is, ''The tailor, which is person who custom sews clothing, usually men's, ripped the suit.'' A more likely sentence is, ''The tailor ripped the suit.'' From this latter sentence, it is difficult to determine what kind of thing (category-based knowledge) a tailor may be. It could be a person, a rowdy dog, a piece of metal. If an individual does not know the meaning of tailor, the information that is most likely to be acquired is that which is physically present and obvious, namely the thematic associations. The individual may be able to conclude category-based knowledge of tailor only after a variety of experiences. In the framework of Landauer and Dumais (1997), well-known words that happen to be thematic associates for a novel word have been integrated into the matrix, and presumably, categorical knowledge about the novel word could be gained indirectly, if the sentence is very simple. In this sense, thematic and categorical knowledge could be acquired simultaneously.

Given this, thematic associates may be acquired first followed by (or at least simultaneously with) categorical knowledge. Shore, Chaffin, Kovach, Whitmore, and Dickens (1996) investigated the types of free associations participants made to known, frontier, and unknown words. Their results indicated that categorical associations were more prevalent for known words, and thematic associations were more prevalent for frontier and unknown words. Thus, the most direct evidence to date suggests that known knowledge is primarily a reliance on categorical associates, whereas frontier and unknown knowledge is primarily a reliance on thematic associates.

The first experiment investigated if known, frontier, and unknown words differ in kind of underlying semantic information and the strengths of these underlying representations. It is predicted that the semantic representations of unknown words are thematic in nature and weak; thematic representations of frontier words are strong, and categorical representations of frontier words, if they exist, are weak. The semantic representations of known words are predicted to be primarily categorical in nature, with weaker or secondary reliance on thematic knowledge. Figure 1 models these predictions.

Given the work of Landauer and Dumais (1997), it is logical that contextual associates would be acquired prior to categorical knowledge. However, we cannot discount the work of Chaffin (1997), which suggests the opposite. To investigate this, a priming paradigm was used. Priming is used to investigate how semantic knowledge is organized by the presentation of a word (called the prime) followed by a related word, unrelated word, or nonword (called the target). The task of the participant is

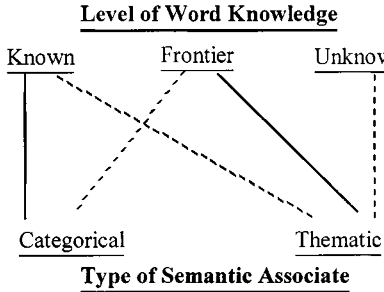

FIG. 1. Predictions of kind and strength of semantic representations underlying known, frontier, and unknown words. Solid lines indicate strong semantic representations (large facilitory priming). Dashed lines indicate weak semantic representations (small facilitory or inhibitory priming).

often a lexical decision about or pronunciation of the target. A common understanding of how word knowledge is organized is that words are incorporated in a semantic network, and the activation (i.e., encountering) of a word enables a spread of activation through the network from strongly to weakly related concepts via conceptual links. Each concept within the network is linked to other concepts by degree of relatedness (Collins & Loftus, 1975) or frequency of association (Conrad, 1972). Within this network, strongly related items, either conceptually or by frequency of association are closely linked and therefore result in faster response times. The usefulness of a priming paradigm is that a brief presentation of a word (prime) activates the semantic network, and lexical decisions to a subsequently presented word (target) may be facilitated if the prime and target are related, fastest to strongly related words and slower to weakly related words. If unrelated targets are responded to more quickly than related targets, this may be due to weak semantic codes (Dagenbach et al., 1990) or conflicting expectancies (suggested by Chiarello, 1991). Neely (1991) presents a detailed review of the literature addressing the use of primes and targets.

EXPERIMENT 1

This experiment was conducted to determine the kinds of words to which activation will spread from known, frontier, and unknown words. If there are only differences in strength of semantic representation between each word level, then priming should be observed for both categorical and thematic targets for all levels of word knowledge, but the strength of facilitation should increase or inhibition should decrease (response times to targets decrease) as word knowledge increases. If only qualitative differences exist, then categorical and thematic targets should be differentially primed depending on word level of the prime, but the strength should remain constant. If qualitative and strength of representation differences exist, then both the pattern and the strength of facilitation and inhibition should be different across word levels.

Two priming with partial knowledge investigations have failed to observe systematic priming effects. Shore (1991) centrally presented low frequency word primes followed by synonym targets. No priming effect was obtained for any of the three levels of word knowledge. Dickens (1995) conducted a similar experiment investigating automatic and controlled priming of words at different levels of knowledge. In the automatic priming experiment, related words were responded to more slowly than unrelated at the unknown level, and no priming was found for known and frontier words. In the controlled priming experiment, related words at the frontier level were responded to faster than unrelated words, and no priming was found for known and unknown words.

The absence of systematic priming effects for frontier and unknown words may be attributed to weak links within the semantic network (weak semantic code), but it is particularly curious that neither Shore (1991) nor Dickens (1995) observed priming for known words when it is clear that semantic knowledge exists. This lack of priming for known words may be due to methodology rather than due to different processes for low frequency words than high frequency words. MacLeod and Kampe (1996) report that low frequency words actually result in more robust priming than high frequency words.

One key methodological feature of both studies was that the priming tasks were tailored to each individual participant by assessing levels of word knowledge prior to the priming task. Theoretically, this method is of sound reasoning to ensure that known, frontier, and unknown words are followed by an equal number of related and unrelated targets. However, completing the Level of Word Knowledge Assessment Task (LOWKAT) first, in which each word is viewed and processed, may have unwittingly resulted in repetition priming effects. Repetition priming typically entails studying a list of words, and then presenting the same word or a synonym (e.g., Roediger & Challis, 1992) as a target after a temporal delay in which several intervening items are also presented (Neely, 1991). Shore (1991) used synonyms as targets, and many (but not all) of Dickens (1995) targets were also synonyms. A priming effect is typically not found with synonyms in a repetition priming paradigm (e.g., Dorfmueller & Schumsky, 1978; Niemi, Vaurus, & von Wright, 1980; Roediger & Challis, 1992; Shulman, 1970; Warren, 1977).

Additionally, the literature on spreading activation would suggest that participants underwent some semantic processing following the initial presentation of known, frontier, and unknown words on the LOWKAT. It is therefore possible that the delay between the LOWKAT and the priming task was a sufficient time to enable a very extensive spread of activation throughout the semantic network, effectively saturating the network. The delay between LOWKAT and priming task may not have been long enough for activation to dissipate. Robust repetition priming effects have been observed after 64 s (Dannenbring & Briand, 1982), and to slowly decay over 45 min (McKone, 1995), so it is possible that there was residual activation of the primes (and perhaps targets) that lasted the duration of the priming task. While both Shore and Dickens did not intend to measure repetition priming, they may have done so inadvertently. To determine if presenting the LOWKAT prior to the priming task may contaminate priming effects, Experiments 1 and 2 will vary the task order.

Another methodological issue of Shore (1991) and Dickens (1995) is the delay between onset of the prime and onset of the target (Stimulus Onset Asynchrony, SOA). Shore (1991) and Dickens (1995) both used an SOA = 2 s, and the automatic priming experiment of Dickens used an SOA of 250 ms. The long SOA may have been too long and activation may have spread along many different pathways that ultimately resulted in activation of concepts that are either indirectly related to the low frequency prime–target pair or the participant is no longer using the prime cue to make a lexical decision about the target (hence, no priming effect). The 250-ms SOA of Dickens (1995) may have been too short to enable a detectable amount of spreading activation to directly related semantic links. Neely (1991) suggests that the optimal SOA for priming effects is 500 ms. This SOA was used in Experiments 1 and 2.

Method

Participants. Sixty-seven students enrolled in various Psychology courses at the Richard Stockton College of New Jersey participated for extra credit. The participants were not matched on any variables.

Choice of low frequency words. Four pretests were designed to determine 90 specific low frequency words to be used in the priming experiments. The first pretest was an attempt to identify 90 low frequency words likely to be known, frontier, and unknown words (for a complete description of the method for determining known, frontier, and unknown levels, please refer to Experiment 1 procedure). This was important for ensuring that each word used was likely to be known, frontier, or unknown for most participants to enable maximal usage of the words chosen. One hundred forty-three words that occur five or fewer times per million words used in the language (Kucera & Francis, 1967) and 20 filler nonwords (constructed by replacing one or two letters of real words while retaining othographic regularity) were tested with 86 participants. It was hoped that known, frontier, and unknown words would be equally distributed throughout the final set of 90 words for most participants. This was not the case. Because of the variability of participants' knowledge of these words, only 50 words had a 50% chance or higher of occurring at one word level. An additional 26 words were selected on the basis that they occurred at any level of knowledge for at least 70% of the participants, and an additional 14 words were selected on the basis that they occurred at any level of knowledge for at least 50% of the participants. Appendix 1 lists this final set of 90 words.

In the absence of published norms, the second pretest was designed to gather common associations to the low frequency words used in the first pretest. This was important to ensure that the targets following low frequency word primes were common associates of that word or clearly associated with each word for the majority of people. This was specifically to avoid experimenter bias. In this pretest, 36 participants did a simple word association task in which they were given a printed list of the 90 words and asked to write the first word that came to mind as they read each one. They were specifically told to work rapidly and without pausing, and also to try to avoid getting into a rhyming pattern. One participant was excluded due to a failure to understand the instructions.

The third pretest was designed to sort the associations gathered from pretest 2 into meaningfully related from the nonmeaningfully related associates. This was done to ensure that the targets chosen for the priming experiments were meaningfully related to the prime, rather than similar in sound, spelling, or idiosyncratic relations. Thirteen participants were provided with the 90 nouns, their definitions, and the associations given for each of the 90 words. The participants then circled all of the associations that they deemed to be meaningfully related to each low frequency word. The 90 words were also printed in list format in a separate booklet for the participants to write additional associations if necessary. In addition, participants were given a separate list of the 90 words and were asked to write a meaningfully related word in the event that none of the associations presented were meaningfully associated.

The fourth pretest was designed to sort the meaningfully related associates into thematic and categorical associations. These final associations were used as targets in Experiments 1 and 2. Fourteen participants were provided with the 90 words, their definitions, and meaningful associations (as judged by one or more participants in pretest 3). Seven of these participants were asked to circle all of the associated words that were categorically related to the low frequency word, and to leave the others blank. The other seven participants were asked to circle all of the associated words that they believed to be thematically related to the word and to leave the others blank. Participants were given oral descriptions of categorical (thematic) associations at the start of the task, and were also provided with written descriptions that remained in their possession for the duration of the task.

Category-based associations were loosely defined in accordance with Chaffin's (1997) categorical (A _____ is a kind of _____) and/or coordinate(A _____ and _____ are similar kinds of things) associates. Both of these were considered in the priming experiments as operational definitions of categorical associates because Chaffin (1997) found these types of relations to be the most prevalent category-based associates. Further, because the final stimuli were based on a word association task, it was impossible to control for the types of associates that participants reported and indeed the purpose of the word association task was empirical and not theoretically driven. Defining categorical associates in these loose terms enabled maximum usage of the word associations. In accordance with Chaffin (1997), thematic associates were defined as two nouns that are typical arguments of the same verb, such as axe and wood, or if the target word and association are both props or actors in the same standard event and therefore, contextually related but not categorically related. Participants were also told to write a good categorical (thematic) association only if they did not believe any of the printed associations to be categorically (thematically) related.

The task used in pretest 4 proved to be somewhat difficult for the participants in the thematic condition. For example, 83% of participants in the thematic condition chose vegetable as thematically related to okra. However, participants in the thematic condition did choose more thematic associations than participants in the categorical condition, suggesting that they did have some understanding of thematic relations, but that it was a difficult task. The difficulty these participants had may stem from the nonmutual exclusivity of these two types of words. For example, KNAVE and MAN can be a categorical association because they are both people, a KNAVE can be a kind of MAN. Similarly, KNAVE and MAN can be viewed as thematically related because a KNAVE can rob a MAN. Thus the type of relationship between MAN to KNAVE is ambiguous.

Given this, only unambiguous thematically related associations (as judged by the experimenter) were chosen as targets to be used in the priming experiments. Therefore, some of the targets chosen are not necessarily those agreed upon as thematically related associations by the majority of participants. The experimenter decided upon thematic associations for those words in which participants in the thematic condition only circled categorical associations. The resulting prime–target pairs used in the priming experiments are shown in Appendix 2.

Materials and apparatus. The LOWKAT consisted of 90 words and 20 pronounceable nonwords. All words and nonwords ranged in length from three to six letters. The frequency of each word's occurrence in the English language ranged from two to five times per million words used in the language (Kucera & Francis, 1967). Nonwords were constructed by changing one or two letters of different low frequency words. Each word and nonword appeared once on the LOWKAT in list format.

The priming task consisted of 240 prime–target pairs presented on a PowerMacintosh computer via MacLaboratory Reaction Time application. All primes were words, half of the targets were words, and half of the targets were nonwords. The 90 primes also appeared on the LOWKAT. Of these 90 primes, 30 were paired with categorically related word targets, 30 were paired with thematically related word targets, and 30 were paired with unrelated word targets. Ninety prime words that did not appear on the

LOWKAT were followed by nonwords. The relatedness proportion (frequency of related words targets/ total frequency of word targets) = 0.67. The remaining 60 trials consisted of neutral prime words (the word BLANK), 30 of which were paired with words and 30 were paired with nonwords.

The Sentence Decision Task consisted of 90 pairs of sentences. Each sentence pair consisted of one sentence that used one of the LOWKAT words correctly, and one sentence that used the word incorrectly. Prior to the construction of sentences, the experimenter decided upon broad categories in which each of the target words belonged (e.g., maud is an exemplar of the clothing category). Correct sentences used the target word in a correct category-based context (e.g., ‘‘the knights were given grog as a treat after the battle’’). Incorrect sentences used the target word in a different (inappropriate) category-based context (e.g., ‘‘the boy used his grog to get to school and back’’).

To control for cues, such as probability of occurrence, that participants may use in choosing the correct sentence, inappropriate categories for incorrect sentences were chosen by first computing the proportions of the 90 words per category, and matching this proportion for incorrect sentences. This was to ensure that the total frequency with which each category was represented in correct sentences was also represented in incorrect sentences. The inappropriate category context chosen for each incorrect sentence in a pair was arbitrary.

Correct and incorrect sentences within pairs were matched for length, the order of correct and incorrect sentences for each pair was counterbalanced, and the order of the sentence pairs was dictated by a random numbers table. The target word in each sentence was underlined, and each sentence in each pair was preceded by either an a or a b.

Design and procedure. The experimental design for the priming task was a 2 (Task Order: LOWKAT first/Priming task second, Priming task first/LOWKAT second) x (3)(Prime Relation: Categorical, Thematic, Unrelated) x (3)(Word Level: Known, Frontier, Unknown) mixed factorial. The dependent variable was response time for lexical decision. Half of the participants did the priming task first, and half of the participants did the LOWKAT first (same procedure as pretest 1). Task order was counterbalanced across participants.

The LOWKAT is divided into four steps. In the first step, participants write a definition or a synonym next to each of the words on the list. They were explicitly told to do this only if they thought they knew the definition or a synonym. After completion of this first step, they were asked to write a meaningful sentence using all of the remaining, blank words. They were also told to do this only if they knew enough about the word to use it correctly in a sentence. Following this, participants were asked to place a check mark next to all the remaining, blank words that were familiar to them prior to their arrival at the experiment, even if they thought they did not know what the word meant. Last, participants were asked to circle remaining items that they believed were real, English words. At this point, they were informed that some of the items were fabrications, and were not words at all.

The priming task required a lexical decision, indicated by pressing different keys on the keyboard. Assignment of response keys was counterbalanced across participants. All prime–target trials began with a centrally presented ‘‘x’’ (500 ms) and a 100-ms alerting tone. All primes were centrally presented for 200 ms, followed by a 300-ms interstimulus interval, upon conclusion of which the target appeared for a duration of 200 ms. Targets were also centrally presented and appeared immediately below the location of the prime. The four-, five-, and six-letter targets subtended 1.8°, 2.1°, and 2.3° of visual angle, and the height subtended 0.6°. All participants did 16 practice trials with the experimenter present, followed by the 240 experimental trials during which the experimenter was not present and the overhead lights were extinguished. The 240 experimental trials appeared in random order.

The last task completed by all participants was the Sentence Decision Task. Participants were instructed to read each pair of sentences, and circle the letter (a or b) in front of the sentence that used the underlined word correctly. They were also instructed not to leave any of the pairs blank, and to guess if they truly could not decide which sentence was correct.

Coding for level of word knowledge. In addition to the method used by Shore and colleagues for determining the known, frontier, and unknown levels of knowledge for each word on the LOWKAT, only those words for which there was a corresponding correct sentence decision were included in subsequent analyses.

Words for which participants wrote a correct definition or synonym or which they used correctly in a sentence on the LOWKAT and chose the correct sentence on the Sentence Decision Task were considered to be at the known level of knowledge. Accuracy of definitions, synonyms, and sentences were decided upon by three independent raters. On the rare occasion that the first two raters did not agree, the third rater decided which was correct, and the author always agreed with these decisions. Words that were checked as familiar on the LOWKAT and correct on the Sentence Decision Task were considered to be frontier, and words that were left completely blank after step 4 on the LOWKAT and were correct on the Sentence Decision Task were considered unknown. Incorrect definitions, synonyms, and sentences, and also circled words, or nonwords checked as familiar or circled were considered to be false alarms and subsequently discarded. There may be some interesting implications of the circled words for semantic acquisition, but given that there are no theoretical speculations regarding them, and there are no theoretical antecedents to render a systematic analysis of these words, they were excluded.

It should be noted that Shore and colleagues did not use correct sentence decisions as part of the criteria for known, frontier, and unknown words because correct sentence decisions was their dependent variable. In the present experiments correct sentence decisions were used as partial operational definitions of each word level because they provide the clearest evidence of underlying semantic knowledge for frontier and unknown words. Discarding words that were checked as familiar with corresponding incorrect sentence decisions was done to guard against overly liberal checking behaviors. Overly liberal checking behaviors may result in coding words as frontier, when they may be unknown or novel to the participant. These inconsistencies (checked as familiar, but incorrect on the sentence decision task) were discarded to reduce the variability in the response times on the priming task.

Similarly, words left completely blank without corresponding correct sentence decisions were discarded because of the likelihood that at least some of these words had actually never been seen before by participants and therefore, semantic knowledge was truly nonexistent. Although the sentence decision task is not an absolute indicator of the existence of semantic knowledge, there is no other way to parse the unknown words from those that have truly never been seen before. Discarding words left completely blank with corresponding incorrect sentence decisions was done to obtain a set of unknown words for which participants had the highest chance of possessing semantic knowledge, and to therefore reduce the variability in response times.

Results

Mean response times and standard deviations of the priming task were computed across all participants and conditions. Only response times that were between 2.5 standard deviations above and below the mean were included in further analysis. Response times beyond this range were discarded (less than 1% of responses).

To obtain a cell mean for each participant, a minimum of two responses per cell was the criterion. When this was not possible due to only one response or no responses for a given participant within a given cell, the mean for the participant was replaced with the overall mean for the cell. One response was replaced per cell for known words with categorical, thematic, and unrelated targets. Three responses were replaced for frontier words with categorical targets, four responses for frontier words with thematic targets, and four for frontier words with unrelated targets. No responses were replaced for unknown words with categorical targets, one response for unknown words with thematic targets, and zero responses for unknown words with unrelated targets. The total percentage of replacements was 2.48%.

Priming effects (Fig. 3). Priming effects were assessed by subtracting response time to related, and unrelated targets from response time to word targets following neutral primes (neutral–related, neutral–unrelated). The resulting difference scores are submitted to statistical analysis. These analyses were performed to determine if categorical and/or thematic targets were considered to be related to the known, frontier, and unknown words. If the prime and target pair are organized within a semantic network as related, then facilitation (response times to related faster than neutral) should occur. If the prime and target are considered to be unrelated then no priming (response times to related and neutral are equal) or inhibition (response times to related are slower than neutral) should be found.

To determine the existence of facilitory/inhibitory priming effects, the difference scores obtained for each condition were submitted to one sample t tests to determine if they were significantly different from zero. Results of these t tests indicate facilitory priming effects for targets categorically related to known words, $t(66) = 2.649$, $p = .01$; targets thematically related to frontier words, $t(66) = 4.363$, $p < .001$, and unknown words, $t(66) = 1.952$, $p = .05$; and targets unrelated to frontier words, $t(66) = 2.57$, $p < .05$. No significant inhibitory effects were found.

The difference scores were then submitted to a (3)(Word Level: Known, Frontier, Unknown) x (3)(Prime Condition: Categorical, Thematic, Unrelated) repeated-measures ANOVA. No significant main effects were observed for Word Level, $F(2, 132) = 1.85$, $p > .15$, or Prime Condition, $F(2, 132) = 1.85$, $p > .15$; and a marginally significant interaction of Word Level x Prime Condition was observed, $F(4, 264) = 2.04$, $p = .08$.

Planned comparisons reveal no significant difference between responses to categorical targets following frontier and unknown words, $F < 1$, and a marginal difference between thematic target responses following frontier and unknown words, $F(1, 242) = 2.98$, $p = .08$. Interestingly, a difference was not found for categorical targets between known primes and frontier primes, $F(1, 242) = 1.74$, $p > .15$, and a marginal difference was found between known primes and unknown primes, $F(1, 242) = 3.32$, $p = .06$. (See Fig. 2.)

Sentence decisions. To replicate findings of Shore and colleagues, the operational definitions of known, frontier, and unknown words did not include the criterion of correct sentence decisions for these analyses. Rather, proportion of correct sentence decisions became the dependent measures. Proportion of correct sentence decisions was subjected to a one-way ANOVA, $F(2, 132) = 165.69$, $p = .0001$. A higher proportion of correct sentence decisions were made about known words ($M = .98$, $S = .04$) than frontier words ($M = 0.77$, $S = 0.16$), $F(1, 132) = 115.66$, $p = .0001$, and about frontier words than unknown words ($M = 0.63$, $S = 0.10$), $F(1, 132) = 53.91$, $p = .0001$.

Additionally, one sample *t* test against chance suggested that participants chose the correct sentences at above chance levels for known words ($M = 0.98$, $S_x = 0.005$), $t(66) = 95.2$, $p < .001$; frontier words ($M = 0.77$, $S_x = 0.02$), $t(66) = 13.55$, $p < .001$; and unknown words ($M = 0.63$, $S_x = 0.012$), $t(66) = 10.83$, $p < .001$.

Other General Findings:

Neutral conditions. Response times to targets following Neutral Primes were submitted to a one-way (Target Type: Word, Nonword) repeated-measures ANOVA. Word targets ($M = 633.5$, $S = 129.5$) were responded to more quickly than Nonword targets ($M = 779.6$, $S = 173.6$), $F(1, 66) = 115.21$, $p = .0001$.

Nonword target conditions. Response Times to Nonword targets following Neutral and Word Primes were subjected to a one-way repeated-measures ANOVA. Equivalent responding to Nonwords was found, $F < 1$.

Word prime/word target conditions. Response times were subjected to a 2 (Task Order : Prime Task first, Prime Task second) x (3) (Word Level: Known, Frontier, Unknown) x (3) (Prime Condition: Thematic, Categorical, and Unrelated) ANOVA.

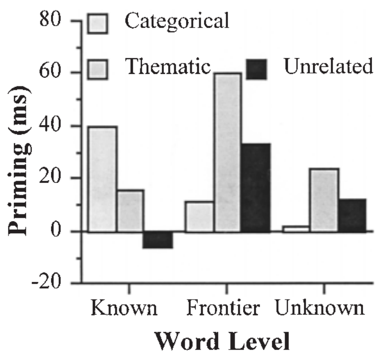

FIG. 2. Priming of categorical, thematic, and unrelated targets by known, frontier, and unknown primes. Significant facilitation was observed for those targets that were categorically related to known primes, and thematically related to frontier primes and also unknown primes. Priming for thematic targets for frontier primes was larger than that obtained for unknown primes. Thematic knowledge appears to be present for early levels of word knowledge, and categorical knowledge does not appear to be acquired until the known level of knowledge.

There was a main effect of Task Order, $F(1, 65) = 4.617$, $p < .05$, in that responses to targets were faster when the priming task preceded the LOWKAT than when it followed ($M = 587.2$, $S = 119.4$, $M = 642.6$, $S = 177.8$, respectively). No main effects of Word Level, $F(2, 130) = 1.48$, $p > .2$, or Prime Condition, $F(2, 130) = 1.83$, $p > .15$ were found.

Planned comparisons suggest that thematic targets were responded to more quickly when followed by frontier primes ($M = 578.8$, $S = 121.4$) than known primes ($M = 623.4$, $S = 190$), $F(1, 260) = 3.65$, $p = .057$, and thematic targets were responded to more quickly than categorical targets ($M = 627.4$, $S = 178.9$) when primed by frontier words, $F(1, 260) = 5.47$, $p < .05$. No other planned comparisons were significant.

Discussion

Experiment 1 was conducted to determine if there are differences in the type of semantic knowledge underlying known, frontier, and unknown words. It was hypothesized that these levels of word knowledge reflect differences in the kind of underlying semantic knowledge and/or the strength of those semantic representations. A second hypothesis was that known, frontier, and unknown levels reflect a nested continuum of acquisition, rather than truly independent types of words. The results provide some support for both of these hypotheses.

Known semantic knowledge appears to include category information, but it appears as though frontier words and unknown words do not include this type knowledge. Additionally, frontier and unknown word knowledge, but not known, appears to include thematic information. The marginally significant difference between thematic targets at the unknown level and those at the frontier level ($p = .08$) may suggest that thematic representations may have gained in strength from the unknown to the frontier level.

To argue for a continuum of knowledge acquisition, there should be evidence of an increase in strength of categorical targets prior to the known level, and facilitation of thematic targets should (1) appear at the known level as it did at the frontier and unknown levels and (2) should increase in strength from the unknown to, at least the frontier level. Although strength of thematic representations may have increased from the unknown to the frontier level, there is no evidence from this experiment that the strength of those representations increased or even remained the same for known words. While it is difficult to imagine that an individual would not have thematic knowledge of known words, a more parsimonious explanation may be that known word knowledge is simply organized differently than frontier and unknown knowledge. Known word knowledge may be organized in terms of categorical knowledge so that the encountering of a known word primarily activates this knowledge, and the priming task in the present experiment did not enable thematic targets to be primed. Known words seem to simply reflect the clear acquisition of categorical knowledge.

Different from known words, frontier and unknown knowledge may be organized in terms of thematic knowledge in the absence of clear categorical knowledge. Consistent with the framework of Landauer and Dumais (1997), early word knowledge appears to reflect the acquisition of contextual associates, and categorical knowledge is secondary to this if acquired at all at the unknown and frontier levels. However, the marginal difference observed for categorical targets between known and unknown words and no such difference found between known and frontier words or frontier and unknown words may suggest that categorical knowledge was in the process of acquisition prior to the known level, but that this knowledge was not strong enough or organized in such a manner to enable priming at the frontier level.

Logically, once categorical knowledge is acquired thematic knowledge can be inferred, and there is no need to maintain at the known level the semantic organization of thematic associates necessary for the frontier level. Once a word becomes known, words that are acceptable contextual associates should become rather flexible. If thematic associates are acquired early due to contextual cooccurrence with unknown or frontier words, then the acquired thematic knowledge is limited. However, if tailor is a known word then thematic knowledge is almost unlimited. Consider the following sentences, ‘‘The tailor owned a cat,’’ ‘‘The tailor ripped my suit,’’ and ‘‘The tailor ate my suit.’’ If tailor is a known word, and categorical knowledge has therefore been acquired, then the only sentence that is nonsensical is ‘‘The tailor ate my suit.’’ However, if tailor is a frontier or unknown word, and therefore only thematic knowledge has been acquired, then the nonsensical sentence must be, ‘‘The tailor owned a cat’’ because tailor and cat are not frequent props in the same context. Having categorical knowledge enables one to replace the word ‘‘cat’’ with almost any other concrete noun (some would be silly, but they would still be plausible). Because of this, it would be uneconomical and inefficient for all thematic associates of known words to be readily and easily accessible. This may explain why there was not priming of thematic targets of known primes in the present experiment.

Further, if thematic knowledge is directly acquired from the context in which a word appears, and is acquired early in the process of meaning acquisition as suggested by the present experiment, the origin of categorical knowledge is unclear. Categorical representations seem to suddenly appear at the known level, even though an individual may have encountered words categorically related to frontier and unknown words in context. One possibility is that categorical knowledge is emergent from thematic knowledge. That is, thematic knowledge is directly acquired from context, but categorical knowledge must be inferred from contextual associates. Using neural network models to simulate the acquisition of knowledge, Elman (1990) has demonstrated that categorical knowledge may indeed emerge from repeated experiences with novel words presented in typical sentence contexts. This may parallel the acquisition of word meanings in the human mind. Increases in exposure to a partially known word (e.g., frontier) in context may result in the emergence of categorical knowledge. The emergence of categorical knowledge may be the difference between a frontier word and a known word.

Last, the present experiment has perhaps provided some insight into why known word meanings can be explicitly accessed, but frontier word meanings are not; and also why frontier words (and known words) are familiar, but unknown words are unfamiliar even though semantic knowledge exists for all three levels. One difference between known and frontier words is the nature of the semantic representation. If, as the present experiment suggests, clear categorical knowledge has not been acquired for frontier words, then a definition (what kind of thing the word is) cannot be recalled simply because it has yet to exist. Thematic knowledge should be sufficient to enable sentence decisions when either general or definitional constraints are violated because the other words may enable the decision. Thus, the qualitative difference in the underlying semantic representations may be one reason for the existence of known and frontier words as two separate levels.

The qualitative difference that seems to distinguish known from frontier and unknown levels of knowledge does not seem to exist between frontier and unknown levels. Rather, both seem to reflect thematic knowledge. However, because there was a significant difference for categorical targets between known and unknown primes, and no difference between known and frontier primes, perhaps frontier knowledge also consists of a minimal amount of categorical knowledge. This minimal amount may enable a feeling of familiarity. Additionally, the marginally significant difference between the facilitation of thematic targets following frontier and unknown primes may indicate that thematic knowledge has gained in strength from the unknown to the frontier levels. Thus, the sense of familiarity may require a certain amount of strength in the underlying thematic representation.

EXPERIMENT 2

The second experiment investigated cerebral asymmetries for the processing of known, frontier, and unknown words. Experiment 1 demonstrated that these three word levels do indeed differ in the kind and strength of their underlying semantic representations. Known words facilitate access to categorical knowledge, whereas frontier and unknown words facilitate access to thematic knowledge, the facilitation from unknown words being weaker than that for frontier. Thus, it appears as though known words incur a spread of activation to category-based knowledge, and frontier and unknown words incur a spread of activation to thematic or context-based knowledge.

The spreading activation process is a generally stable phenomenon, but the underlying neural substrates for any priming effect are not clear. Chiarello (1988) suggests that upon presentation of a prime word, the cerebral hemispheres may simultaneously engage in semantic processing, but the patterns of semantic network activation are qualitatively different. The right hemisphere (RH) appears to activate a broader range of meanings during word recognition than does the left hemisphere (LH) (Chiarello, 1991; Chiarello, Burgess, Richards, & Pollock, 1990). For example, the RH displays equal priming for primes and targets that are contextually associated (e.g., cradle–baby), are categorically associated (e.g., table–bed), and have both types of associations (e.g., doctor–nurse) (Chiarello, Richards, & Pollock, 1992). Priming in the LH occurs largely for words that are both contextually and categorically related (Burgess & Simpson, 1988; Chiarello et al., 1990). Chiarello, Richard, and Pollock (1992) have also found that a priming task that enables the use of a relatedness cue to search or activate the semantic network (large number of related prime-target pairs) results in faster responses to categorically related than associated targets when presented to the LH. This research suggests that LH activation spreads to only the most highly related words, and this includes categorical relations. The RH seems to be indifferent to the type of associate and relatedness cues.

Not only does the LH appear to be more suited to use the cue of predicted relatedness, whereas the RH may be indifferent to this cue (Chiarello, 1985), but it also appears to be more sensitive to degree of relatedness. When type of relation is controlled and degree of relatedness is manipulated, the LH tends to inhibit weakly related words (e.g., dog–goat), but RH presentations result in an equal amount of facilitation for weakly and strongly related (e.g., dog–cat) words (Chiarello & Richards, 1992). The RH seems to activate a broader set of semantically related words and does not distinguish strongly vs weakly related words within that set. The LH, however, may inhibit weakly related words and only activate those words that are most strongly related.

In the present context, it seems likely that the RH may incur a spread of activation from known, frontier, and unknown words to both thematically related and categorically related words. The LH, however, may employ a spread of activation to categorically related words only. It has become common knowledge that the LH is superior to the RH in the decoding of single high frequency, well-known words.

If known word knowledge is a reliance on acquired categorical knowledge and the LH incurs a spread of activation to categorical associates only (word related along both dimensions are not included in the present experiments), then it seems likely that the LH is primarily responsible for selecting a definition of a known word. The RH may contribute to the processing of known words, but its inability to distinguish thematic from categorical associates suggests that, at best, it enhances the LH processing.

If thematic knowledge is primarily relied upon for unknown and frontier words, and the RH is superior to the LH for contextual associates, then the RH should be the primary mediator of participant performance with frontier and unknown words. Furthermore, if the RH is unable to distinguish among types of relations, and is also the mediator of at least frontier words, one possibility for the existence of the frontier level reflects a RH inability to choose a definition from the broad range of activated words. Another possibility is that the frontier level simply reflects a lack of acquired categorical knowledge, and this knowledge may be necessary for definition/synonym recall. If the former is true, and both categorical and thematic knowledge exists for frontier words, then it is expected that there would be equal RH facilitation between categorical and thematic targets at the frontier level. However, if the latter were true and no categorical knowledge exists for frontier words then RH facilitation for thematic targets only would be expected.

Analogous to this reasoning, a form of deep dyslexia resulting from LH damage is characterized by the consistent substitution of synonyms or categorically related words for those words that are physically present in a sentence (e.g., reading ‘‘rock’’ for ‘‘stone’’). It is assumed that these characteristics are a result of RH processes due to damage incurred by the LH (Coltheart, 1983, 1985; Zaidel & Peters, 1981). Upon presentation of a word, the RH may indeed activate a broad range of related words, and this broad range of activation is evident in the type of mistakes made by deep dyslexics. Related word substitutions made by deep dyslexics indicate that the semantic network is being activated, but the actual concept that is being substituted is as strongly activated as related concepts, the substitutes. This word substitution may be the method used by the RH when making sentence decisions about words for which its particular pattern of network activation does not enable a definition to be recalled or narrowed down to the most strongly related word. Burgess and Cushman (1990; Rausch, 1981) have also observed that RH-damaged patients show evidence of activating fewer multiple meanings of ambiguous words than neurologically intact counterparts, and LH-damaged patients evidence the activation of multiple meanings.

One implication of this is a critical role of the RH in the acquisition of meaning. This implication has received some empirical support (e.g., Eisele & Aram, 1993; Mills, Coffey-Corina, & Neville, 1993; Selnes, Niccum, Knopman, & Rubens, 1984; Wert, 1993). Furthermore, while the LH is superior to the RH for decoding of words, the RH is also quite capable of processing semantic knowledge (Coslett & Saffran, 1989a, 1989b; Dennis, Lovett, Wiegel-Krump, 1986; Gazzaniga, 1970; Gazzaniga & Sperry, 1967). If high frequency words are primarily processed by the LH, and the RH plays a critical role in early acquisition of word meanings, then at some point in the acquisition process, perhaps between frontier and known levels, there is a lateral shift in processing dominance from the RH to the LH. Goldberg and Costa (1981) have also suggested that a shift from the RH to the LH in processing dominance may require the formation of categorical networks. In this sense, Experiment 2 investigates whether known word knowledge is ‘‘categorical enough’’ to reveal a LH superiority.

Because facilitation was observed for categorical associates only for known words

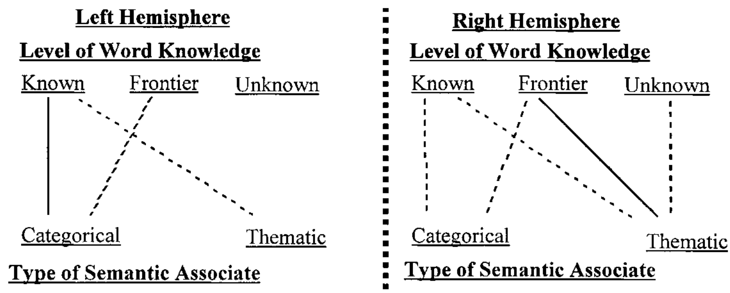

FIG. 3. Predictions of kind and strength of underlying semantic representations utilized by the left and right cerebral hemisphere in the processing of known, frontier, and unknown words. Solid lines indicate strong semantic representations (large facilitory priming). Dashed lines indicate weak semantic representations (small facilitory or inhibitory priming).

in Experiment 1 it is predicted that this is primarily due to LH processes. One might assume that under conditions of central presentation, it would be ideal if both cerebral hemispheres contributed their particular abilities to word processing. However, if this were true, and the processing of known words was due to both LH and RH contributions, then some facilitation of thematic targets of known primes should have also been observed (RH process), in addition to the observed facilitation of categorical targets for known primes (both LH and RH processes). Because these were not the findings, the simplest argument is that the LH processes known words.

Additionally, it is also predicted that the RH is primarily responsible for the facilitation of thematic targets of frontier and unknown words. It was also speculated in the discussion of Experiment 1 that perhaps some categorical knowledge had been acquired by the frontier level, but that it was not enough to enable facilitation. If frontier words have categorical representations that were not observed under central presentation conditions then these representations may reflect LH metacontrol. Metacontrol is when both hemispheres have access to the same information, and there is a neural mechanism that determines the mode of processing that is characteristic of either the LH or the RH (Hellige & Michimata, 1989a, 1989b; Levy & Trevarthen, 1976). If the LH assumes metacontrol, and because categorical targets of frontier words were not facilitated in Experiment 1, these representations must be weak because of the LH tendency to distinguish between strength of relation. If the RH does not distinguish between categorical and thematic associates, and there is indeed some categorical knowledge underlying frontier words, then frontier words presented to the left visual field/RH should result in equal facilitation of thematic and categorical targets. If categorical knowledge about frontier words has not been acquired, then only left visual field/RH facilitation of thematic targets should be observed.

The second experiment investigated three main hypotheses: (1) The LH facilitates categorical knowledge, and the right hemisphere facilitates thematic knowledge. (2) The LH facilitates categorical knowledge of known words, and inhibition should be observed for categorical and thematic knowledge of frontier and unknown words. The RH will equally facilitate categorical and thematic knowledge of known words, but only thematic knowledge of frontier and unknown words. (3) There is the existence of a lateral shift in processing dominance from the RH to the LH as word knowledge increases (see Fig. 3 for specific patterns of facilitation and inhibition of words related to known, frontier, and unknown words).

Method

Participants. Sixty students enrolled in various Psychology courses at the Richard Stockton College of New Jersey participated for extra credit. The participants were not matched for age, gender, or ethnicity.

Materials and apparatus. The apparatus and materials for Experiment 2 were identical to those of Experiment 1.

Design and procedure. The experimental design was a 2 (Task Order: LOWKAT first/Priming task second, Priming task first/LOWKAT second) × (3)(Prime Relation: Categorical, Thematic, Unrelated) × (3)(Word Level: Known, Frontier, Unknown) × (2)(Visual Field: Left Visual Field/Right Hemisphere, Right Visual Field/Left Hemisphere) mixed factorial. Similar to the first experiment, half of the participants did the priming task first, and half of the participants did the LOWKAT first. Again, task order was counterbalanced across participants.

The LOWKAT procedure was identical to that of pretest 1. The only Priming Task difference between Experiment 1 and Experiment 2 was the location of the target, and the instructions. All primes were centrally presented for 200 ms, followed by the 300-ms interstimulus interval, upon conclusion of which the target was presented to the Left Visual Field/ Right Hemisphere or the Right Visual Field/ Left Hemisphere for a duration of 200 ms. Additionally, the central ''x'' reappeared at the offset of the prime and remained until the offset of the target. The four-, five-, and six-letter targets were subtended 4.2°, 4.5°, and 4.7° of visual angle from the central fixation ''x'' to the outermost letter. The height of the prime and the targets subtended 0.6° of visual angle. Participants were instructed to maintain fixation on the central ''x'' throughout the experiment because the purpose of the study was to determine their ability to make decisions about stimuli that they were not directly looking at. Similar to Experiment 1, participants completed 16 trials with the experimenter present and 240 experimental trials in the absence of the experimenter and the overhead lights extinguished.

The last task completed by all participants was the Sentence Decision Task, and the procedure was identical to that of Experiment 1.

Coding for Level of Word Knowledge was identical to that for Experiment 1.

Results

Mean response time and standard deviation were computed across all participants and conditions. Response times that were between 2.5 standard deviations below and above the mean were considered for analysis. Response times beyond this range were discarded (less than 1% of responses).

Similar to Experiment 1, when a participant had less that two responses per conditions, their mean response times were replaced with the overall mean response time of the condition. Two responses were replaced for the lvf/RH, 2 for the rvf/LH known prime–thematic target condition, 1 for the lvf/RH, 5 for the rvf/LH known prime–categorical target condition, 4 for the lvf/RH, and 3 for the rvf/LH known prime–unrelated target condition. Eleven responses were replaced for the lvf/RH, 13 for the rvf/LH frontier prime–thematic target condition, 14 for the lvf/RH, 12 for the rvf/LH frontier prime–categorical target condition, 9 for the lvf/RH, and 12 for the rvf/LH frontier prime–unrelated target condition. Six responses were replaced for the lvf/RH, 2 for the rvf/LH unknown prime–thematic target condition, 8 for the lvf/RH, 2 for the rvf/LH unknown prime–categorical target condition, 8 for the lvf/RH, 2 for the rvf/LH unknown prime–unrelated target condition. A total of 10.4% of responses were replaced with the means of their respective cells.

Priming effects (Fig. 4). One sample t tests were computed from obtained difference scores (Neutral–Related, Neutral–Unrelated) to demonstrate the existence of priming effects. Facilitation was only observed for lvf/RH target presentations, and inhibition was found only for rvf/LH target presentations.

Lvf/RH facilitation occurred for targets thematically related to known words, $t(59) = 2.684$, $p < .01$, and frontier words, $t(59) = 3.932$, $p < .001$; for categorically related targets to known words, $t(59) = 5.583$, $p < .0001$; and for targets unrelated to known words, $t(59) = 2.933$, $p < .01$, and unknown words, $t(59) = 2.969$, $p < .01$. No inhibitory effects were found for lvf/RH target presentations.

Rvf/LH inhibition occurred for targets thematically related to frontier words, $t(59) = -2.506$, $p = .01$, and unknown words, $t(59) = -2.259$, $p < .05$; for targets categorically related to unknown words, $t(59) = -2.445$, $p < .05$; and for targets unrelated to known words, $t(59) = -2.925$, $p < .01$, frontier words, $t(59) = -1.853$, $p = .06$, and unknown words, $t(59) = -2.910$, $p < .01$.

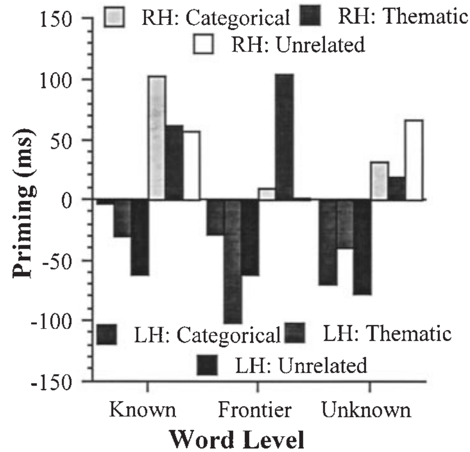

FIG. 4. LH inhibition and RH facilitation of targets related and unrelated to known, frontier, and unknown primes. All significant facilitory priming effects were restricted to the right hemisphere, and all inhibitory priming effects were restricted to the left hemisphere. RH facilitation was found for categorical and thematic targets of known primes, and also thematic targets of frontier primes. LH inhibition was found for targets categorically related to unknown primes and thematically related to frontier primes. RH thematic knowledge appears to be present early, followed by the presence of categorical knowledge at the known level . Conversely, LH categorical knowledge may be present earlier than thematic knowledge. The hemispheres seem to acquire different kinds of knowledge at different rates.

To determine if the facilitation observed under central presentation conditions of Experiment 1 is due to combinatory processes of the RH and LH, additional *t* tests were computed by collapsing across visual field. The only significant priming was facilitation of targets categorically related to known words, $t(119) = 49.878$, $p < .0001$. No other combined lvf/RH and rvf/LH effects that mirror Experiment 1 were found, suggesting that the processing of words at different levels of knowledge under central conditions is not merely additive LH and RH processes.

Difference scores were subjected to a (3)(Word Level: Known, Frontier, Unknown) × (3)(Prime Condition: Thematic, Categorical, Unrelated) x (2)(Visual Field: lvf/RH, rvf/LH) repeated-measures ANOVA. Significant main effects of Word Level, $F(3, 177) = 3.228$, $p < .05$, and Visual Field, $F(1, 59) = 47.716$, $p =. 0001$, were found. No main effect of Prime Condition was found, $F(2, 118) = 1.0$, $p > .3$.

There was more priming from known words ($M = 21.2$, $S = 175.44$) than frontier words ($M = -12.18$, $S = 247.85$), $F(1, 18) = 4.94$, $p < .05$. No difference was found between frontier and unknown ($M = -11.45$, $S = 204.83$) primes, $F < 1$. The main effect of visual field is due to faster response times (facilitation) for lvf/RH trials ($M = 50.856$, $S = 202.29$) than rvf/LH trials (inhibition) ($M = -52.452$, $S = 208.76$). No significant two-way interactions were obtained for Word Level × Prime Condition, $F(4, 236) = 1.2$, $p = .3$; Word Level × Visual Field, $F < 1$; or Prime Condition × Visual Field, $F(2, 118)$. A significant three-way interaction of Word Level × Prime Condition × Visual Field was found, $F(4, 236) = 4.239$, $p < .01$.

Simple comparisons revealed a marginally significant difference between rvf/LH inhibition of thematic targets for frontier and unknown words, $F(1, 236) = 3.45$, $p = .06$. No inhibitory difference was found between unknown prime categorical and thematic targets, $F < 1$. Additionally, while inhibition of targets categorically related to unknown words only was observed, no priming differences were observed between known and frontier rvf/LH categorical targets, $F < 1$.

Simple comparisons revealed no significant difference between lvf/RH presentations of targets thematically related to known and frontier words, $F(1, 236) = 1.75$, $p > .15$, or between categorical and thematic targets for known primes, $F(1, 236) = 1.59$, $p = .2$. (See Fig. 4.)

General Findings

Neutral prime conditions. Mean response times to targets following neutral primes were subjected to a (2)(Target Type:Word, Nonword) × (2) (Visual Field: left, right) repeated-measures ANOVA. Main effects of Target Type, $F(1, 59) = 107.67$, $p = .0001$, indicate that words ($M = 1058.5$, $S = 206.6$) were responded to more quickly than nonwords ($M = 1219.4$, $S = 214.4$); and Visual Field, $F(1, 59) = 21.406$, $p = 0001$, indicates that rvf/LH presentations ($M = 1108.7$, $S = 222.4$) were responded to more quickly than left visual field/ Right Hemisphere lvf/RH ($M = 1169.2$, $S = 224.4$) presentations. A significant interaction of Target Type × Visual Field, $F(1, 59) = 16.742$, $p = .0001$, was also found.

Simple comparisons indicate that word targets were responded to more quickly when presented to the rvf/LH ($M = 1007.3$, $S = 192.8$) than the lvf/RH ($M = 1109.7$, $S = 208.8$), $F(1, 59) = 49.876$, $p = .0001$; no difference for response times to nonwords were found between the lvf/RH and rvf/LH, $F(1, 59) = 1.628$, $p > .2$.

Nonword target conditions. Response times to nonword targets were subjected to a (2)(Prime Type: Neutral, Word) × (2)(Visual Field) repeated-measures ANOVA. Nonword targets following neutral primes did not differ from those following word primes, $F < 1$. There was a marginally significant main effect of Visual Field, $F(1, 59) = 3.528$, $p = .06$, with faster responses to nonword targets presented to the rvf/LH (LH: $M = 1226.5$, $S = 216.3$; lvf/RH: $M = 1203.9$, $S = 204$).

Word prime and target conditions. Response times were submitted to a 2 (Task Order: Prime Task first, second) × (2)(Visual Field: Left, Right) × (3)(Prime Condition: Categorical, Thematic, Unrelated) × (3)(Word Level: Known, Frontier, Unknown) mixed ANOVA. The only significant main effect was found for Word Level, $F(2, 116) = 3.244$, $p < .05$ (Task Order, $F < 1$; Prime Condition, $F(2, 16) = 1$, $p > .3$; Visual Field, $F < 1$). Targets of known word primes ($M = 1037.3$, $S = 218.9$) were responded to more quickly than frontier words ($M = 1070.7$, $S = 260.9$), $F(1, 116) = 4.97$, $p < .05$, and no difference was observed between targets of frontier and unknown words, $F < 1$.

Results also indicate a significant two-way interaction of Task Order × Visual Field, $F(1, 58) = 4.75$, $p < .05$. When the LOWKAT preceded the priming task, responses to targets presented to the LH were slower ($M = 1087.6$, $S = 276.9$) than when the LOWKAT followed the priming task ($M = 1031.9$, $S = 190.2$). Task order did not affect response times on RH trials.

A significant interaction of Visual Field × Prime Condition x Word Level, $F(2, 232) = 4.20$, $p < .01$, was also observed. Simple comparisons suggest that frontier word categorical targets ($M = 1035.3$, $S = 145.3$) were responded to more quickly than thematic targets ($M = 1108.2$, $S = 340.8$) for LH trials, $F(1, 232) = 4.9$, $p < .05$. However, frontier word thematic targets ($M = 1004.6$, $S = 190.2$) were responded to more quickly than categorical targets ($M = 1100.3$, $S = 240.1$) for RH trials, $F(1, 232) = 8.45$, $p < .01$. Additionally, frontier word thematic targets were responded to more quickly when presented to the RH than the LH, $F(1, 232) = 9.9$, $p < .01$; and frontier word categorical targets were responded to more quickly when presented to the LH than the RH, $F(1, 232) = 3.9$, $p < .05$. There was no difference between unknown word categorical and thematic targets for LH, $F < 1$, or RH trials, $F < 1$.

Sentence decisions. Proportions of correct sentence decisions were subjected to a one-way ANOVA, $F(2, 118) = 108.07$, $p = .0001$. A higher proportion of correct decisions were made about sentences using known words ($M = 0.98$, $S = 0.04$) than frontier words ($M = 0.75$, $S = 0.19$), $F(1, 118) = 93.92$, $p = .0001$; and frontier than unknown ($M = 0.64$, $S = 0.14$) words, $F(1, 118) = 22.36$, $p = .0001$.

One-sample t tests against chance indicate that participants chose the correct sentences with greater than chance probabilities for known words ($M = 0.98$, $S_x = 0.005$), $t(59) = 95.4$, $p < .001$; frontier words ($M = 0.75$, $S_x = 0.026$), $t(59) = 9.61$, $p < .001$; and unknown words ($M = 0.64$, $S_x = 0.018$), $t(59) = 7.78$, $p < .001$.

Discussion

One goal of Experiment 2 was to determine the extent to which known, frontier, and unknown words prime their respective semantic representations in the left and right cerebral hemispheres. It was hypothesized that facilitation of targets categorically related to known words would occur for both LH and RH presentations. Facilitation of targets thematically related to known, frontier, and unknown words was hypothesized to occur on RH trials only. It was further hypothesized that frontier and unknown word knowledge is not inclusive of categorical representations, and facilitation of these targets was not expected for either LH or RH presentations.

Consistent with the predictions, equal facilitation was observed for RH presentation of targets categorically and thematically related to known words, and frontier words facilitated thematically related targets only. The lack of RH facilitation for categorical targets of frontier words suggests that frontier words may not have underlying categorical representations. This is also consistent with the findings of Experiment 1. Additionally, the equal facilitation of RH presentations of thematic and categorical targets for known word primes suggests that categorical knowledge has been acquired by the known level.

The facilitation of unrelated targets observed for known and unknown words is curious, and may be a reflection or side effect of a generally diffuse RH spread of activation proposed by Chiarello and colleagues. The utility of a broad spread of activation may be for locating semantically related words in addition to a general search of the semantic network. A general search strategy may be beneficial for resolving ambiguous sentences, comprehension of familiar phrases and context for which there is a clear RH advantage (Brownell, Michel, Powell, & Gardner, 1983; Brownell, Potter, Bihrle, & Gardner, 1986; Foldi, 1987; Van Lancker & Kempler, 1987).

The seeming ability of the RH to simultaneously locate related words and employ a general search strategy in the event that an utterance is ambiguous is most impressive (arguably words presented in isolation, as in the priming task, are ambiguous to the RH). Further, the facilitation of words unrelated to unknown words may suggest that thematic (and categorical) representations are too weak to be located as related, but that a simultaneous general search strategy is automatically employed. Similarly, the RH facilitation of known word categorical, thematic, and unrelated targets may more strongly suggest that these two different search strategies (general and constrained) are employed by the RH, one that searches for related targets and locates thematic and categorical representations, and a general search mechanism that locates other possibilities.

Interestingly, while all facilitory effects were restricted to RH presentations, all inhibitory effects were restricted to LH presentations. The inhibition of targets can be indicative of weak semantic representations (e.g., Dagenbach et al., 1990) or the expectancy of a target different from that which was presented (e.g., Neely, 1976, 1977). The general findings that responses were slower for LH trials if the priming task followed the LOWKAT suggest that participants may have formed some expectations about the prime words, and that those expectations were dissimilar to the targets. This may further suggest that the LH semantic representations of frontier and unknown words are not thematic or categorical in nature, but are based on some other kind of representations. These ''other'' kinds of representation may be semantic in nature or completely unrelated to the meaning of the word. For example, LH representations of frontier and unknown words may be phonological or orthographic, and not semantic. Using a controlled priming paradigm where participants are biased toward forming expectancies, Chiarello (1985, Experiments 1 & 2) found that the LH was more suited to use phonological cues than orthographic, suggesting that any LH nonsemantic expectancies for unknown and frontier words may be phonological in nature, not orthographic. Similar findings of a LH superiority for phonological processes have also been observed in commissurotomized patients (e.g., Zaidel & Peters, 1981) and normals (e.g., Crossman & Polich, 1988; and Zecker, Tanenhaus, Alderman, & Sisqueland, 1986). This would further suggest that any semantic processing of at least frontier words is mediated by the RH, and that the nature of this processing is a search for thematic representations.

The disappearance of LH inhibition for targets categorically related to frontier words and for targets thematically related to known words may suggest that LH expectancies may be shifting toward categorical and thematic representations. At the frontier level, the LH may have acquired a weak categorical representation, but the lack of priming and the retained inhibition for thematic and unrelated targets suggest that the primary expectancies are still different. Additionally, by the known level, the inhibition of unrelated targets with no priming for related targets suggests that different expectancies still exist, but that both categorical and thematic representations may be weak. Therefore, while some minimal categorical knowledge may have been acquired by the frontier level, and minimal thematic knowledge may have been acquired by the known level, this knowledge was not strong enough to enable facilitation. The kinds of semantic or nonsemantic representations of known words that more accurately reflect LH expectancies have not been tapped into by this experiment.

Last, there appears to be no clear lateral shift in processing dominance from the RH to the LH as word knowledge increases. Rather, the LH seems to contribute very little to the processing of known, frontier, and unknown words. However, it has become common knowledge that the LH is superior to the RH for the decoding of single well-known/high frequency words (for review see Bradshaw & Nettleton, 1983). From the perspective of a learner, novel words may progress through unknown, frontier, and known levels of knowledge, and then may become well-known, if the word appears with high frequency for the learner. If, as the present research suggests, the RH plays a major role in the semantic processing of at least frontier and known words, then at a level beyond known words a lateral shift in processing dominance does indeed occur. Additional ''levels'' beyond the known level may be simple frequency thresholds or the acquisition of additional semantic representations. Nonetheless, the present research suggests that the RH has acquired strong thematic representations by the frontier level, and strong categorical representations by the known level. Conversely, the LH may have acquired minimal/weak categorical representations by the frontier level, and minimal/weak thematic representations by the known level.

Interestingly, the RH appears to acquire thematic knowledge prior to categorical knowledge, but the LH may acquire categorical knowledge prior to thematic knowledge (if at all). These different and opposite response patterns force the conclusion that the cerebral hemispheres simply acquire word meanings in qualitatively different ways and at different rates. Any lateral shift in processing dominance may therefore be due to different propensities of each hemisphere, and not because the RH has acquired a minimal knowledge base that the LH builds upon.

GENERAL DISCUSSION

The present research began with two basic questions: Why is there explicit access of semantic knowledge underlying only known words, when it is evident that semantic knowledge also exists for frontier and unknown words; and how can semantic knowledge exist for both frontier and unknown words, but only frontier words are familiar? The experiments reported herein tested the possibility that differences between these word levels may reflect differences in kind and/or strength of semantic representations.

Under conditions of central presentation (Experiment 1), known words facilitate access to categorical representations whereas frontier and unknown words facilitate access to thematic representations. Thus, one difference between words at the known level and the other two levels is the kind of semantic representations that are facilitated. Recall of a definition (known words) may require the acquisition of categorical representations. Similarly, under conditions of central presentation, the only observed difference (albeit, marginal) between frontier and unknown words was in the strength of facilitation of thematic targets. Familiarity (frontier words) may require a certain strength of semantic representation that is present at the frontier level, but not at the unknown level. Also interesting was the finding of no difference between known and frontier word categorical targets, and a significant difference between known and unknown categorical targets. This enabled the possibility that some categorical knowledge had been acquired by the frontier level, but was too weak to enable facilitation. However, this seems to be unlikely due to the failure to obtain facilitation of categorical targets presented to the RH for frontier words in Experiment 2. Therefore, any difference between frontier and unknown words appears to be in the strength of the underlying thematic representations, rather than kind.

To the extent that known words have semantic representations different from those of frontier and unknown words, they may also have different neural representations. It was predicted that more facilitation of categorical targets for known words would occur during LH than RH trials, and that facilitation of targets thematically related to frontier and unknown words would occur during RH trials only. Inherent in this is the possibility of a lateral shift in processing dominance from the RH to the LH between the frontier and the known levels. Because no evidence of a complete lateral shift was found, and all facilitory effects were restricted to RH presentations, processing of known, frontier, and unknown words may not be mediated by globally different neural substrates. Rather any neural differences that may exist are within the RH, and local, within-hemisphere differences were not tested by these experiments. However, some evidence of LH acquisition of categorical knowledge appears at the frontier level (inhibition disappears) and thematic knowledge appears at the known level (inhibition disappears). One implication of this is that the cerebral hemispheres differ in the kind and rate of word meaning acquisition. A second implication is that known, frontier, and unknown words may be reliant on the same neural substrates tapping into a general pool of resources. Known, frontier, and unknown word knowledge may be contained within this general pool of resources, and the encountering, i.e., activating, of these words results in a spread of activation that locates all existing knowledge for these words. While the end product may be different (locating categorical, thematic, or both kinds of representations), the means to that end is the same, and seemingly RH-mediated.

Also interesting about these two experiments is that neither hemisphere exactly mirrors the findings of central presentation conditions, nor did analyses from Experiment 2 that collapsed across visual field. The conclusion that thematic and not categorical representations exist for frontier words was the only finding demonstrated by both Experiments 1 and 2. The lack of any RH priming of targets thematically related to unknown words can be attributed to a lack of power, but most curious is the different priming effects obtained between central and lateral conditions for known word primes.

In Experiment 1, only categorical targets were facilitated and in Experiment 2 RH presentation facilitated both categorical and thematic targets but LH presentation facilitated neither target type. However, because of the RH facilitation of categorical targets, it is likely that the same observed under central conditions is due to RH processes. If the RH is presumably causing the facilitation of categorical targets, then why not also facilitate thematic targets under conditions of central presentations similar to the lateral presentations? Recall that the research on metacontrol by Hellige and colleagues found that when both hemispheres have access to the same information (bilateral or central conditions), the resulting behavior appears to reflect processes available to both hemispheres. From the research of Chiarello and colleagues, both hemispheres can process categorical relations. It may be that under conditions of central presentation there is metacontrol favoring processing of categorical representations. While it may be the RH that is causing the central facilitation of categorical targets, thematic targets are not likewise facilitated because both hemispheres are not capable of processing such representations.

This raises one final interesting point. The RH may be a central executor of metacontrol, not assuming that metacontrol is a ‘‘meeting of the minds,’’ so to speak, or that metacontrol requires the involvement of an independent modulating structure. At least with respect to word level, the RH may assume the role of a central executive that is aware of the capabilities of other neural structures and distributes responsibility accordingly, or at least provides the basic knowledge necessary for local experts. Under conditions of central presentation where the requirement is the simple semantic decoding of single words, the ‘‘local experts’’ should be within the LH. In these experiments, they seem to be within the RH. The RH, as a central executive, may be initiating the categorical processing, and the LH is failing to build on this due to a lack of strength in the appropriate representations.

APPENDIX 1

143 Concrete Nouns and 30 Nonwords used in Pretest 1

143 Words				**30 Nonwords**
abode	ewer	lichen	pyx	vade
abyss	eyrie	ligand	ravine	absor
acacia	facet	linden	rogue	ality
adage	fane	lute	rowel	ardout
aglet	fedora	lynx	sachem	astune
alkali	feint	maget	saga	bawf
alloy	flange	magma	salve	dubess
aurora	flax	mana	scions	eclu
azalea	floc	manse	scribe	edirt
bale	foray	marmot	sedge	flosh
bard	gable	mastic	sine	heder
bedlam	gaggle	mastiff	sloth	jisk
bezel	galley	maud	sod	kell
bile	gauss	melee	sortie	kob

APPENDIX 1—*Continued*

143 Words				30 Nonwords
bilge	gazebo	mien	spectre	lecant
bisque	gilt	mough	spire	lepity
bleb	gorge	mung	sumac	leprae
bloke	grog	newts	synod	nux
burlap	gypsum	niche	tarn	nyle
cabana	gyve	nomad	teredo	ochor
cache	helion	ocarina	thane	ribble
cameo	idyl	ocelot	thew	ronnel
chive	inlet	offal	tryst	skulp
coffer	julep	omen	tureen	tofe
convoy	kale	pallor	vale	trask
corpus	kayak	pape	vellum	traven
crag	kebob	patina	zealot	wazo
despot	keel	peen		wode
diadem	kiosk	peltry		wreab
dirge	klaxon	pennon		zuche
dolt	knave	pestle		
edict	lamina	phlox		
enigma	lark	pith		
eparch	lathe	poplin		
ethos	lecher	pram		
eulogy	legume	priory		

APPENDIX 2
Primes and Targets Used in
Experiments 1 and 2

	Prime	Category target	Thematic target
1.	Abode	house	family
2.	Abyss	void	ocean
3.	Adage	story	wisdom
4.	Aglet	clasp	shoe
5.	Alloy	metal	ring
6.	Azalea	bush	garden
7.	Bard	singer	tale
8.	Bile	fluid	liver
9.	Bilge	ship	water
10.	Bleb	bubble	foot
11.	Bloke	fellow	pants
12.	Burlap	fabric	sack
13.	Chive	herb	potato
14.	Coffer	box	jewels
15.	Convoy	group	wagon
16.	Crag	rock	cliff
17.	Despot	ruler	castle
18.	Diadem	tiara	gem
19.	Dolt	boy	school
20.	Eparch	king	region
21.	Eulogy	speech	death
22.	Ewer	bottle	wine
23.	Eyrie	home	eagle
24.	Facet	part	stone
25.	Fedora	hat	head
26.	Feint	joke	clown
27.	Flange	device	pipe
28.	Flax	plant	yarn
29.	Floc	cotton	feather
30.	Galley	room	ship

APPENDIX 2—*Continued*

	Prime	Category target	Thematic target
31.	Gazebo	porch	party
32.	Grog	beer	pub
33.	Gyve	chains	prison
34.	Hovel	hut	hermit
35.	Inlet	sea	coast
36.	Julep	drink	glass
37.	Kabob	meat	grill
38.	Kayak	boat	lake
39.	Kiosk	stall	news
40.	Klaxon	horn	sound
41.	Knave	thief	money
42.	Lark	bird	nest
43.	Legume	bean	chef
44.	Lichen	moss	rock
45.	Linden	tree	park
46.	Lynx	bobcat	jungle
47.	Magma	lava	island
48.	Manse	estate	farm
49.	Marmot	rodent	plains
50.	Mastic	glue	paper
51.	Maud	scarf	custom
52.	Melee	battle	crowd
53.	Mung	turf	cow
54.	Newt	frog	swamp
55.	Niche	hole	shelf
56.	Nomad	gypsy	camel
57.	Ocelot	cat	prey
58.	Offal	waste	pig
59.	Okra	food	dish
60.	Omen	symbol	seer
61.	Onus	chore	maid
62.	Pallor	color	face
63.	Pape	robin	wings
64.	Patina	rust	copper
65.	Peen	tool	nail
66.	Pelty	fur	hunter
67.	Phlox	flower	spring
68.	Pith	core	seed
69.	Poplin	cloth	dress
70.	Pram	cart	baby
71.	Priory	chapel	nun
72.	Ravine	gulf	leaves
73.	Rogue	liar	crime
74.	Rowel	spur	cowboy
75.	Sachem	indian	tribe
76.	Saga	drama	opera
77.	Salve	drug	rash
78.	Scribe	author	book
79.	Sedge	grass	mud
80.	Sine	math	angle
81.	Sloth	animal	forest
82.	Sortie	jets	war
83.	Spire	spear	tower
84.	Sumac	weed	woods
85.	Synod	senate	church
86.	Teredo	snail	shell
87.	Thane	knight	sword
88.	Tureen	bowl	soup
89.	Vale	hill	horse
90.	Zealot	fan	belief

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