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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

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 sen-

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 quantita-

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

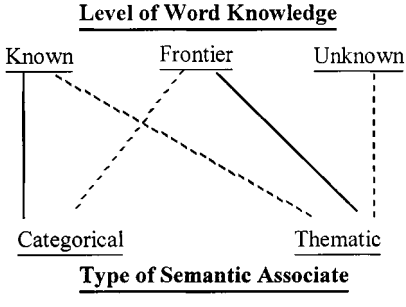


**FIG. 1.** Predictions of kind and strength of semantic representations underlying known, frontier, and unknown words. Solid lines indicate strong semantic representations (large facilitory priming). Dashed lines indicate weak semantic representations (small facilitory or inhibitory priming).

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 Assess-

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

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

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

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.

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also consists of a minimal amount of categorical knowledge. This minimal amount may enable a feeling of familiarity. Additionally, the marginally significant difference

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

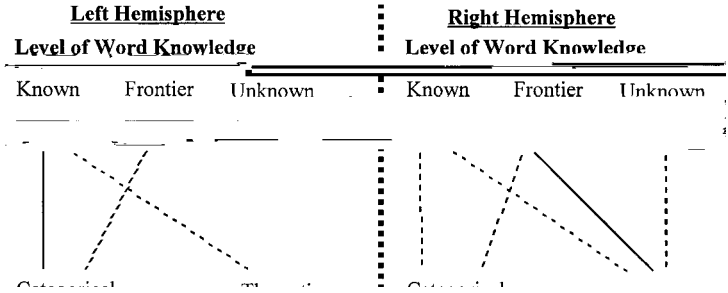


**FIG. 3.** Predictions of kind and strength of underlying semantic representations utilized by the left and right cerebral hemisphere in the processing of known, frontier, and unknown words. Solid lines indicate strong semantic representations (large facilitory priming). Dashed lines indicate weak semantic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

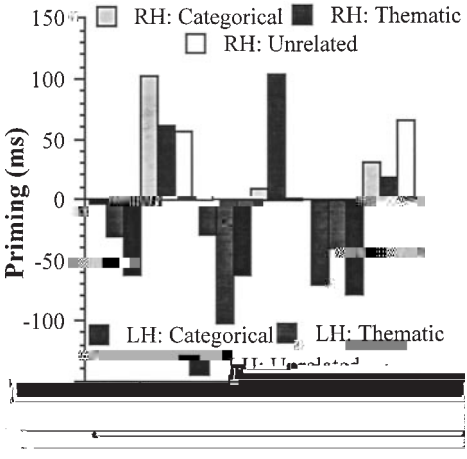


**FIG. 4.** LH inhibition and RH facilitation of targets related and unrelated to known, frontier, and unknown primes. All significant facilitory priming effects were restricted to the right hemisphere, and all inhibitory priming effects were restricted to the left hemisphere. RH facilitation was found 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

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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 [illegible]

ted to the LH than the RH, $F(1, 232) = 3.9$, $p <$

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 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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