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## Some Principles of the Organization of Verbs in the Mental Lexicon

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We tested the organization of verbs in semantic memory in terms of five semantic relations. These relations are modeled on, but different from, those commonly assumed to organize the noun lexicon. In a restricted association task, subjects were given 30 seconds to generate verb-only responses to a verb stimulus, and the responses were classified in terms of the five relations. 28 different verb stimuli were selected from pairs that had been identified as examples of the relations under study. When idiosyncratic responses were discounted, the five relations accounted for 94% of all responses. The dominant relation, accounting for about 25% of the answers, turned out to be troponymy, the hyponymic *manner-of* relation, which links verbs like *munch*, *eat*, and *consume*. The second most frequent responses (14.4%) were examples of entailment, as between *dream* and *sleep*, followed by synonymy (*shout-holler-yell*) with 13.5% of the answers, and opposition relations (such as *enter-exit*) with 8%. The least frequently generated responses (4.1% of the total) represented the presupposition relation (exemplified by *cure-treat*.) For verbs that have a "tree" structure with three or more lexicalized taxonomic levels, associations seem to be strongest between the superordinate and what might be a "basic" level, while higher-level verbs are rarely generated. The semantically more elaborate troponyms also enter into opposition relations with each other, unlike the verbs on the superordinate level. Some verbs have a relatively "flat" structure, and are linked only to antonyms and synonyms; the organization of these verbs, which tend to cluster in the *change* verb lexicon, resembles that found for adjectives. The results lend support to a model of the structure of the verb lexicon based on these relations.

### 1. Conceptual Relations Among Verbs as the Organizing Principle of the Mental Lexicon

The typical high school graduate knows upwards of 40,000 words (Miller, 1988.) The organization of such a large number of words in the mental lexicon is commonly assumed to be in terms of semantic relations connecting the words to each other (see Evens, 1988, for a summary.) Miller (1969) noted that much of the available association data (Kent and Rosanoff, 1910; Russell and Jenkins, 1954; and Woodrow and Lowell,

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1916) could be interpreted in the light of two semantic relations, hyponymy and meronymy. Hyponymy, a relation based on category membership, links words such as *robin* and *bird*, where the former can be said to be *a kind of* the latter. Words related by hyponymy are believed to be stored together (Collins and Quillian, 1969, Neisser, 1988, and others), making this relation a major organizer of the mental lexicon. Evidence also exists for an organization in terms of meronymic (or part-whole) relation, which relates words like *wheel-car* and *tree-forest* (Chaffin, Herrmann, and Winston, 1988; Winston, Chaffin, and Herrmann, 1987). Hyponymy and meronymy are relations that appear to be best fitted to nouns and noun concepts (Beckwith, Fellbaum, Gross, and Miller, to appear.) Less attention has been focused on the relations among other parts of speech. Gross, Fischer, and Miller (1989) showed that adjectives are organized in terms of antonymy and similarity relations, and that these relations hold between individual lexical items, rather than between entire concepts that can be expressed by more than one word.

The purpose of the present inquiry is to identify the major semantic relations between verbs by means of an association task.

Few attempts have been made to study the organization of verbs (but see Rifkin, 1985, and Rips and Conrad, 1989.) Fellbaum and Miller (to appear) suggest, contrary to Rips and Conrad (1989), that the organization of verbs differs substantially from that of nouns. Instead of hyponymy, they posit a manner, or "troponymy", relation (from Greek *tropos*, fashion or manner). Thus, *nibble*, *munch*, and *gorge* are troponyms of *eat*, in that they refer to manners of eating ("manner" here denotes a variety of semantic elements, such as speed, direction, location, time, intent, quantity, etc.)

The relation of troponymy has been extensively employed in the construction of WordNet, an on-line lexical database constructed on the basis of theories of human lexical organization (Miller et al., 1988; Beckwith et al., to appear; Fellbaum, ms.) Postulating this relation made it possible to cast the English verb lexicon into a tight network, but its usefulness in constructing such a network did not in itself constitute any evidence for the existence of troponymy as an organizer of the mental lexicon. The present study was intended to provide just such evidence.

The relation of synonymy has also been assumed to be a strong organizer of both the noun and the verb lexicon. Furthermore, we test the status of antonymous relations as organizers of the verb lexicon. Such pairs as *rise-fall*, *shout-whisper*, and *enter-exit* represent different kinds of opposition (Cruse, 1986; Lyons, 1977.) The verbs in each pair are always co-troponyms, i.e., daughters of the same superordinate, but they elaborate the concept expressed by that superordinate in contrasting ways. In such opposite pairs as *tie-untie*, one member refers to the undoing or reversing of the action denoted by the other member. Opposite pairs like *give-take* and *question-answer* are converse and symmetric, in that the action denoted by one member results in the action referred to by the other member, but performed by a different participant.

Three additional relations have been postulated as organizers of the verb lexicon. They are variations of a relation termed "entailment" by Fellbaum and Miller (to appear). It was argued there that this relation is the analog of the part-whole relation among nouns. In most cases, verbs denoting activities cannot be broken down into other verbs referring to sequentially ordered subactivities. The closest approximation to meronymy

among verbs can be found in such verb phrases as *write a paper*, denoting events or "script"-like activities (Schank and Abelson, 1977) that can be broken down into sub-activities like *submit*, *proofread*, etc. Note that these component activities tend not to be lexicalized, but are referred to by entire verb phrases. To derive "parts" of most English verbs, one could undertake a semantic decomposition. However, this approach would, in most cases, not yield verbs but, rather, such components as causation (cf. the celebrated example of *kill*.) negation, and aspect. While these meaning components often have a morphological surface realization (such as affixes of various kinds,) they can usually not be expressed as independently lexicalized verbs. The "entailment" relation that Fellbaum and Miller postulate instead is based on the notion of entailment, or strict implication, in logic, where a proposition *P* is said to entail a proposition *Q* iff there is no conceivable state of affairs that could make *P* true and *Q* false. Entailment here denotes the relation between two verbs  $V_1$  and  $V_2$  that holds when the statement *Somebody V<sub>1</sub>-s* entails the statement *Somebody V<sub>2</sub>-s*. For example, entailment relates such verbs as *snore* or *dream* and *sleep*, and also *drive* and *ride*, where the former activity always entails, and overlaps temporally with, the latter (i.e., you cannot snore or dream without sleeping at the same time.)

Another, similar, relation is a kind of backward presupposition; this relation is illustrated by such pairs as *succeed-try* and *digest-ingest*. Unlike the verbs in the entailment relation, the verbs in this relation are not linked by temporal inclusion: you must have performed the presupposed action prior to the presupposing one.<sup>1</sup>

The purpose of the present study was to see whether the semantic relations described above (synonymy, troponymy, antonymy, entailment, and presupposition) really do serve to organize people's verb lexicon. Subjects' generation of verbs associated with a stimulus verb shows whether the relations of the stimulus and the subject-generated verbs are of the kind we have postulated here. Another study, which we will report on separately, tests subjects' ability to recognize our hypothesized relation by distinguishing one verb pair from a set of pairs as being an instance of that relation and as differing from other relations. This has been shown to be the case for hyponymy and meronymy among nouns. People recognize that *robin:bird* and *oak:tree* are examples of the same relation, and that these pairs differ from those like *neck:giraffe* and *petal:flower* (Chaffin and Herrmann, 1988a.) In the present study, we tested subjects' ability to produce verbs related in the five ways outlined above.

## 2.0 The Restricted Association Task

Our specific aim was to test the reality of the semantic relations between verbs that underlie the structure of WordNet. In the association task that we report here subjects were asked to restrict the associations they produced to verbs. This restriction is

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<sup>1</sup> Verbs linked by troponymy, such as the pair *traipse-walk*, are always linked by a (temporally including) entailment relation: a verb referring to the elaboration of another verb always entails the unelaborated verb. Similarly, entailment always accompanies certain kinds of opposition or antonymy (e.g., both members of the pair *enter* and *exit* entail *walk*.) And some verb pairs are linked by both an opposition and a presupposition relation: *tie-untie*. These secondary relations are not the subject of our study here.

somewhat artificial in that people clearly do not form mental associations between words and concepts represented by one type of syntactic category only. We also performed an unrestricted association task experiment, where subjects' responses to verb stimuli were not restricted to verbs; the results of this study, which will be reported on elsewhere, should reflect the structure of the mental lexicon more accurately.

## 2.1 Method

Eleven subjects were each given 28 verbs as stimuli. The 28 verbs were chosen from pairs representing typical examples of the five different relations used to code verbs in WordNet (synonymy, antonymy, troponymy, entailment, and presupposition.) From each such pair, only one verb was chosen. All of the stimuli are words occurring relatively frequently in the language ( $X=32.4$ , Francis and Kucera, 1982.) Thus, *rise* was chosen from the pair *rise-fall*, coded in WordNet as opposites, and *waltz* was selected from the pair *waltz-dance*, illustrating the relation of hyponymy (troponymy). Besides its one prominent relation to another verb, each verb is usually connected further to other verbs, and we expected the different responses to show these diverse relations.

Eleven students in an Experimental Methods Class at Trenton State College were each given a note pad on which they were instructed to write down all the verbs that came to their minds after the stimulus verb had been read aloud. They were told to use a different page to record their responses to each stimulus. For each stimulus, they were given 30 seconds to respond.

## 2.3 Results

The two authors independently rated the responses in terms of the five semantic relation holding between the stimulus and the response. For each relation, we had formulated an illustrative sentence with one slot each for the stimulus and the response verb. When appropriate, we differentiated between the cases where the response occurred either in the first or in the second slot in the sentence. For example, the sample sentence for the troponymy relation was *To \_\_\_ is to \_\_\_ in some manner*. If the troponym constituted the response (in the first slot), the answer was rated as *T1*. If the superordinate term (in the second slot) was generated, the response was classified as *T2*. This directional distinction was also relevant in the cases of entailment and presupposition, but not for the "symmetric" relations of synonymy and antonymy. The overall agreement rate was 83.5%. Disagreements, which were resolved by discussion, were generally due to a coder's failing to recognize a low frequency sense of the response.

The average number of responses by the eleven subjects to each of the 28 stimuli was 36.85. Of these responses, an average of 23.96 per stimulus fell into one of the categories we had identified. Table 1 lists the frequencies with which the eleven subjects responded to each stimulus word. The frequencies are means taken across the 28 different stimulus words. Frequencies are given separately for each of the five relations under study, totalled across the five relations, and for responses that could not be classified in terms of the five relations. The relations under study accounted for 65% of all responses. The first row of the table gives the frequencies for all responses. When idiosyncratic responses were eliminated by looking only at words generated by more than

two subjects, the proportion of responses accounted for by the relations under study rose to 94%. Frequencies for words given by more than two subjects are listed in the second row of the table.

Inspection of the top row of Table 1 shows that the relation that appeared most frequently in the subjects' responses was troponymy (25.1%), with entailment (14.4%), synonymy (13.5%), and antonymy or opposition (8%) appearing with intermediate frequencies, and presupposition (4.1%) having the lowest frequency. These differences were significant,  $F(4,108)=6.43$ ,  $p<.001$ . The ordering of frequencies was the same for words given by more than two subjects, shown in the second row of Table 1,  $F(4,108)=4.86$ ,  $p<.001$ . The ordering of relations was also largely the same when only the first response to each stimulus was counted. The frequencies for first responses are shown in the third row of Table 1. Again, troponymy accounted for the most frequent (27.0%), and presupposition for the least frequent (3.2%) responses. The ordering of the relations with intermediate frequencies differed from that for all responses. Synonymy appeared almost as frequently as troponymy (22.1%), with antonymy (15.9%) and entailment (13.3%) appearing somewhat less frequently. The difference in the frequency of the five relations for the first responses was reliable,  $F(4,108)=3.38$ ,  $p<.001$ .

### 3.0 Discussion

The results of this experiment lends support to our hypothesis about the mental organization of the verb lexicon, in that 65% of the responses could be classified in terms of the semantic relations postulated; this figure rises to 94% when idiosyncratic answers given by less than two subjects are eliminated. These answers often denote verbs that are in a co-ordination relation with the stimulus (such as *read-write*), or co-troponyms of the stimulus (such as the responses *rumba*, *cha-cha*, and *mambo* given to the stimulus *waltz*.) The results permit a more fine-grained analysis of the structure of the verb lexicon and the distribution of some of the semantic relations within the verb lexicon.

#### 3.1 Troponymy

Troponyms elaborate the concepts expressed by their superordinate by adding some fairly specific manner component, which, in a semantic decomposition, could be expressed by means of an adverb or an adverbial phrase. Lexicalization is richest on the subordinate level of the troponyms, because a number of manner elaborations are usually possible for a given superordinate. Opposition relations among verbs tend to be found only among the troponyms, where the oppositions derive from the manner elaboration (e.g., *gobble* and *nibble* constitute a pair of opposing co-troponyms of *eat*.) The same kind of manner relation does not exist between the superordinates (such as *eat*, *drink*, and *write*) and their respective superordinates (*consume* and *communicate*, respectively), which seem somewhat more "remote." The same turned out to be true for contact verbs, such as *hit* and *break*, which are rich in troponyms but tend not to have antonyms on the superordinate level. Fellbaum (ms.) notes the general infelicitousness of transitivity statements involving verbs, which can be attributed to subtle differences in the relations between verbs that are separated by more than one level. On the analogy of Rosch's et al. (1976) important work on noun concepts, one might argue that the troponyms constitute

"basic-level" verbs. The manner elaborations that are part of the troponyms' elaborate semantics and whose differentiating function shows up in the opposition relations between the troponyms correspond to the large number of attributes characteristic of the basic level noun concepts studied by Rosch et al. Our results indicate that associations are strongest between the level of the troponyms and their superordinate (e.g., *munch* and *eat*.) rather than between the superordinate and its higher term (such as *eat* and *consume*.)

Subjects generated troponyms and superordinates with about equal frequency (12.6% and 12.3%, respectively.) The number of troponymic and superordinate responses to a particular stimulus depended on the level of the stimulus in its particular hierarchy. Some verbs do not have lexicalized superordinates, such as the verb *hit*, which elicited mostly troponyms like *bang*, *knock*, *punch*, and *slap*. Others do not have troponyms, such as *waltz*, which elicited its superordinate, *dance*, 11 times. In the cases of verbs that have three or more lexicalized taxonomic tiers, responses were generally limited to verbs on what might be termed the "basic" and "superordinate" levels, and subjects did not generate words from further "up" or "down" in the hierarchy. "Basic-level" verbs elicited most frequently their superordinates (for example, *sip* elicited *drink* 10 times,) while a superordinate, such as *eat*, elicited its respective superordinate "genus" term, *consume*, only once, and generated more troponyms, such as *gobble*, *gorge*, *dine*, *crunch*, *devour*, *binge*, and *stuff*.

### 3.2 Synonymy and Antonymy

While some verbs have the "vertical" structure with at least three taxonomic levels that we saw in the cases of *eat* and *drink*, there are other verbs whose structure seems to be flat, or "horizontal." These verbs are related to synonyms and verbs expressing an opposition, but they have no superordinate and few troponyms. The stimulus *shout*, for example, produced mostly synonyms, such as *bellow*, *yell*, *holler*, and only a few superordinates, such as *tell*, *voice*, *talk*, *interject* and *speak* (24 and 5 responses, respectively.) Another example is *close*, which generated both its antonym *open* and its synonym *shut* with equal frequency (10 responses each,) but only 5 hyponyms. Similarly, *respond* elicited most frequently a synonym *answer* (10 times) and an opposite term *question* (5 times); the superordinate term *talk* was given only twice. *Exhale* elicited its lexical and semantic opposite *inhale* (7 times,) and its entailed verb *breathe* (10 times.) *Enter* elicited its "clang" opposite, *exit*, most often, but also two other opposites, *leave* and *go*. *Enter* and *respond* exhibit a structure resembling the one found for adjectives (Gross et al., 1989), where two adjectives form a strong opposition, and where each of these "direct antonyms" in turn is related to its synonyms, which constitute "indirect antonyms." In WordNet, verbs with such a relatively "flat" structure tend to cluster in the *change* verb group, where opposition is heavily represented as a major relation in this part of the lexicon.

### 3.3 Entailment and Presupposition

The entailment relation with temporal overlap between the activities denoted by the two verbs was represented in a number of responses, such as *snore* and *dream* to the stimulus

*sleep*. Here, the stimulus constitutes the entailed verb, and the responses the entailing activity. By contrast, *steer* elicited the entailed verbs *drive* (four times); and *chase* most frequently generated its entailed activities *run* (7 times) and *follow* (6 times). In terms of a taxonomic structure, the subjects generally moved "up", rather than "down."

Finally, we also found evidence that the presupposition relation functions as an associative link. Subjects responded to the stimulus *marry* with the presupposed verbs *love* (4 responses) and *engage* (2 responses). *Win* elicited *try*, *compete*, and *gamble*. Other clear examples were the frequent responses *treat* and *medicate* for the stimulus *cure*. As in the examples of entailment, subjects generally moved "up" in the hierarchy, from presupposing to presupposed verb.

#### 4.0 Conclusion

The results of our study give evidence for the mental organization of the verb lexicon in terms of semantic relations between verbs. The five relations that were specifically tested all appear to serve as links between verbs, with some relations playing a more prominent role within the verb lexicon than others. The responses elicited by our stimuli indicate that the *manner-of* relation, or troponymy, is the most important organizer of the verb lexicon, followed by entailment, synonymy, opposition relations, and presupposition.

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## Appendix

Table 1  
Mean Response Frequencies Across Stimulus Words (N=28),  
Classified by Relation, for Eleven Subjects

### Relation of Response to Stimulus

	Synonym	Antonym	Troponym	Entailment	Presupp.	Total for all Relations	Other Responses
<b>All Responses</b>	4.93	2.93	9.18	5.46	1.50	23.96	12.89
<b>Responses given by more than two subjects</b>	3.61	2.39	5.89	3.86	.86	16.60	1.29
<b>First Response</b>	2.43	1.75	2.93	1.46	.36	8.93	2.07