The Structure of the Verb Lexicon: Evidence from a Structural Alignment Approach to Similarity

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Abstract

Two different views of the organization of verbs in the mental lexicon have been formulated in recent years: the matrix view and the cluster view. The matrix view suggests that a verb shares as many features with verbs from other clusters as it shares with verbs from its own cluster. Thus, instead of being organized, like concrete nouns into well-defined hierarchies, verbs in the mental lexicon form a matrix like structure. While admitting differences between the organization of verb and noun lexicons, the cluster view claims that verbs form hierarchically organized clusters that resemble noun hierarchies in many ways. We report one study that extends research on similarity of nouns to verbs in order to shed light on these accounts. Subjects were presented with pairs of verbs and asked to list their commonalities or differences. The obtained patterns of commonalities, alignable and nonalignable differences are similar to the patterns obtained for hierarchies of nouns and are consistent with the cluster view of verb organization.

Recent years have witnessed an increase in interest in the development and organization of the mental lexicon for verbs. Issues that have drawn considerable attention include the way early verbs are acquired,(Tomasello & Merriman, 1995), the degeneration caused by neurological trauma (McCarthy & Warrington, 1994), and the organization of verbs in the lexicon (Cruse, 1986; Talmy, 1985).

In this paper we address the issue of the semantic organization of verbs in the mental lexicon. It has been known for more than two decades that verbs, unlike nouns do not appear to be organized into elaborate, tree-like hierarchies, but rather seem to form clusters of semantically close items (Miller, 1972). However, the individual members of a particular cluster can have connections not only with other members of the same cluster, but also with members from relatively distant clusters, thus forming web-like structures. These two aspects of verbs have led to two distinct proposals about the structure of the verb lexicon: the matrix view and the hierarchical view

The matrix view claims that verbs have so many connections to verbs from clusters other than their own, that it is better to conceptualize verbs as being organized in a matrix, rather than in a hierarchy (Huttenlocher & Lui, 1979). According to this view, "the ratio of features a verb shares with other verbs within its field in relation to the features it shares with verbs from other fields is not as large as it is for concrete nouns. In short, certain important features of verb meaning (semantic field, manner, intention, and number and type of arguments) are relatively uncorrelated, resulting in a matrix-like organization of unordered meaning elements.". (Huttenlocher & Lui, 1979, p. 155). Similar assertions were put forth by researchers studying the acquisition of the role argument structure and the semantics of interpersonal verbs (Au, 1986).

In contrast, the hierarchical view states that verbs are indeed organized into hierarchies but that, compared to noun hierarchies, these hierarchies "tend to have a much more shallow, bushy structure; in most cases, the number of hierarchical levels does not exceed four." (Miller & Fellbaum, 1991, p. 217). On this view, a major organizing principle underlying verb hierarchies is *troponymy* – a special kind of hyponymy. In noun hierarchies individual nouns are connected via hyponymy, an asymmetric and transitive relation, familiarly known as the *ISA* relation. That is, noun *x* is a hyponym of noun *y* if the statement 'An *x* is a *y*' is true (e.g., A robin is a hyponym of a bird because the sentence 'A robin is a bird' is true.). However, this test sentence for hyponymy is awkward when applied to verbs (or even gerunds formed from verbs). For example, the sentence 'To stroll is a kind of to walk.' is awkward, suggesting that the sentence frame for testing hyponymy between verbs must be modified. One modification that has been used is to recast the relation between verbs in terms of another aspect of the verbs like manner (e.g., 'To V1 is to V2 in some manner.' as in 'To stroll is to walk slowly.'). This kind of hyponymy is called troponymy. It can be based on a variety of semantic components of a verb including manner, cause, speed, medium, degree of force and so on (Miller & Fellbaum, 1991).

Similarity within and across Hierarchies

In this paper, we suggest that research on the similarity of nouns in taxonomic hierarchies can be extended to examine the matrix and cluster views of verb organization. In order to make this proposal, we must first briefly describe research on the structural alignment view of similarity, and its application to taxonomic hierarchies in nouns.

The structural alignment view of similarity, which is derived from research on analogical reasoning (Gentner,

1983, 1989; Holyoak & Thagard, 1989), suggests that similarity comparisons are well characterized as the alignment of structured relational representations. This view suggests that comparisons of pairs of items yield commonalities and two types of differences – those that are related to commonalities (called *alignable differences*), and those unrelated to commonalities (called *nonalignable differences*) (Markman & Gentner, 1993, 1996). For example, in the comparison of a car and a motorcycle, the fact that both have wheels is a commonality, the fact that each has different numbers of wheels is an alignable difference, and the fact that a car has windshield wipers but a motorcycle does not is a nonalignable difference.

The structural alignment approach was applied to the well known finding that the middle level of taxonomic hierarchies (e.g., car) is privileged over more abstract categories (i.e., superordinates) and more specific categories (i.e., subordinates) in a variety of tasks. A common explanation of basic level superiority is the differentiation view, which suggests that basic level categories have both a high level of within-category similarity and a high level of between-category dissimilarity. From the perspective of structural alignment, this explanation is underspecified, because it does not state whether the high degree of dissimilarity between categories is a function of pairs of contrasting basic level categories having few commonalities or pairs of contrasting basic level categories having many alignable differences.

Markman and Wisniewski (1997) examined this issue by having people list the commonalities and differences of pairs of basic level categories from the same superordinate, as well as pairs of basic level categories from different superordinates and pairs of superordinates. They found that people can list many commonalities and alignable differences for basic level categories from the same superordinate, but few commonalities or alignable differences for pairs of basic level categories from different superordinates or from different superordinates. This finding suggests that pairs of contrasting categories from within a superordinate exhibit a qualitatively different pattern of dissimilarity than do pairs of categories from different superordinates.

This approach can be profitably applied to comparisons of verb pairs in order to distinguish between the matrix and cluster views of verb organization. An extreme matrix-based view of verb organization suggests that a verb shares as many features with verbs within its semantic cluster as it does with verbs from other clusters. In contrast, a hierarchical view suggests that two verbs that are troponyms of the same superordinate will yield many commonalities and alignable differences, just like pairs of basic level categories that are hyponyms of the same superordinate. On this view, a verb has much more in common with verbs from the same cluster (both from the same level and from different hierarchical levels) than with verbs from other clusters (hierarchies).

In the study we present here, participants listed the commonalities or differences of a variety of verb pairs. The verbs were drawn from different hierarchically organized clusters generated from troponymic hierarchies in WordNet (Miller, 1990). In this study, we used superordinate verbs as well as midlevel verbs that are troponyms of the superordinates. In a design analogous to the one used by Markman and Wisniewski (1997), participants saw five different types of verb pairs: Pairs of superordinates, pairs of midlevel verbs that are troponyms of the same superordinate, pairs of midlevel verbs that are troponyms of different superordinates, a superordinate and one of its troponyms, and a superordinate paired with a troponym of a different superordinate.

If the matrix view is correct then there will be no significant differences in the pattern of commonalities, alignable and nonalignable differences listed as a function of the type of pair. In contrast, on the hierarchical view there should be a pattern of results analogous to that obtained by Markman and Wisniewski (1997). In particular, pairs of superordinates, pairs of midlevel categories that are troponyms of different superordinates and superordinates paired with troponyms of different superordinates should yield few commonalities, few alignable differences and relatively many nonalignable differences. In contrast, pairs of midlevel categories that are troponyms of one superordinate, and superordinates paired with their own troponyms should yield many commonalities, many alignable differences and few nonalignable differences.

Experiment

Method

Participants. Participants were 72 members of the Columbia University community. Seventy one people were paid for their participation, and one person received course credit.

Materials. The stimuli were composed from 12 superordinate verb categories and 2 midlevel categories that were troponyms of each superordinate, for a total of 24 midlevel verbs. These superordinates and troponyms were taken from WordNet (Miller, 1990). Table 1 shows the verbs that were used in this experiment.

Table 1: Superordinate categories and their troponyms

Superordinates	Troponyms
to communicate	to talk, to write
to damage	to break, to burn
to decrease	to shorten, to shrink
to destroy	to raze, to wipe out
to feel	to look, to see
to grow	to develop, to rise
to ingest	to drink, to eat
to move	to run, to walk
to protect	to cover, to guard
to remove	to peel, to take off
to strike	to hit, to slap
to transport	to bring, to carry

Each subject saw 18 pairs of verbs. The pairs were constructed in the following way. Six of the superordinate verbs were paired together yielding 3 Super-Super pairs. Three of the remaining six superordinates were paired with one of their troponyms yielding 3 Super-Midlevel (same) pairs. The last three superordinates were paired with troponyms from other superordinates yielding 3 Super-Troponym (different) pairs. The remaining midlevel verbs were paired among themselves in the following fashion. Three troponyms of a superordinate were paired with the other three troponyms from the same superordinate yielding 3 Midlevel-Midlevel (same) pairs. The remaining 12 midlevel verbs were randomly paired yielding 6 Midlevel-Midlevel (different) pairs. This procedure was repeated three times resulting in 3 different sets of stimuli.[1]. Each set was given to 24 subjects. For any given pair of stimuli, half of the participants listed commonalities and half listed differences.

A booklet containing one complete set of stimuli was constructed for every subject. One stimulus pair was placed on the top of each booklet page along with instructions to list commonalities or differences for that pair. Half of the tasks in each booklet required listing commonalities and half required listing differences. Thus, two subjects were needed for one complete run – one to list commonalities of a pair, and the other to list differences. The order of pages was randomized for each subject.

Procedure. Subjects were given booklets and were instructed to write down either the commonalities or the differences of each pair. They were allowed to proceed at their own pace. The task took approximately 30 minutes to complete.

Scoring. The data were scored by the first author using a procedure and operational definitions similar to those used by Markman and Wisniewski (1997) and Markman and Gentner (1993).

Each characteristic that subjects listed as true of both verbs was counted as one commonality (e.g., for verbs *to walk* and *to run* 'Both are active.' or 'Both are forms of movement.'). However, commonalities reflecting grammatical (e.g., 'Both are sometimes transitive.') or lexical characteristics (e.g., 'Both begin with a consonant.') were not counted.

One alignable difference was counted for every instance where a subject attributed different values along a common aspect to verbs from one pair (e.g., 'To run is faster than to walk.' or 'To run is fast and to walk is slow.' or 'To run is fast and to walk is not [fast].'). However, 'To run is fast.' without any reference to the other verb was considered a nonalignable difference, as was any other difference that could not be classified as alignable.

[1]However, the composition of the subsequent sets was partially determined by the composition of the first set. If, for example, a verb was in a Super-Super pair in the first set, it was in the Super-Midlevel (same) pair in the second, and in the Super-Midlevel (different) in the third. The same approach was used for pairs of midlevel verbs as well.

One association was counted for every instance in which subjects made up a sentence stating some causal, or other, relation between the verbs without actually saying anything about their semantic relations (e.g., for the verbs *to run* and *to damage*, 'If you run too much you can damage your joints.')

To assess reliability of the scoring, a representative subset of the data was scored by a naive rater. The interrater agreement was 83%. Most of the disagreements involved alignable differences that were mistakenly called commonalities by one of the raters.

Results

Item analyses were done on the data. The results are consistent with the proposal that verbs are organized into hierarchies. Figure 1 shows the mean listed commonalities (COMM), alignable differences (AD) and nonalignable differences (NAD) as a function of comparison type.

Looking first at the commonalities, a one way ANOVA revealed significant differences between conditions, $F(4, 49) = 7.34$, $p<.01$. Consistent with the hierarchical view, Super-Midlevel (same) pairs yielded significantly more commonalities than Super-Super pairs, $t(16) = 3.38$, $p<.05$,[2] more than Super-Midlevel (different) pairs, $t(16) = 5.51$, $p<.01$, and more than Midlevel-Midlevel (different) pairs, $t(25) = 3.96$, $p<.05$. Similarly, Midlevel-Midlevel (same) pairs elicited significantly more commonalities than Super-Midlevel (different) pairs, $t(16) = 3.36$, $p<.05$.

Surprisingly, a one way ANOVA for the mean number of listed alignable differences was not significant, $F(4, 49) = 1.59$, $p>.10$. However, the contrast that is most relevant from the structural alignment point of view yielded a significant difference. Midlevel-Midlevel (same) pairs elicited significantly more alignable differences than Super-Super pairs, $t(16) = 2.01$, $p<.05$. This finding is important because it corroborates the claim that the representational structures of verbs from within the same hierarchy have much more in common than the representational structures of verbs from different hierarchies.[3]

Significant differences were found in the mean number of nonalignable differences listed for the comparisons in this study, $F(4, 49) = 3.82$, $p<.01$. Overall, the pattern of listed nonalignable differences was the opposite of that obtained

[2]The alpha levels for all post-hoc tests are corrected using the Bonferroni adjustment.

[3]At the more general level, the structural alignment view is supported by the patterns of correlations that we obtained. There was a significant positive correlation between the number of listed commonalities and the number of alignable differences ($r(52) = 0.41$, $p<.01$) and a significant negative correlation between commonalities and nonalignable differences ($r(52) = -0.39$, $p<.01$). In addition, there was a significant negative correlation between commonalities and associations ($r(52) = -0.57$, $p<.01$). and a significant negative correlation between alignable differences and associations ($r(52) = -0.27$, $p<.05$). In contrast correlations between nonalignable differences with either alignable differences or associations were nonsignificant.

for the commonalities and alignable differences – Super-Super pairs elicited significantly more nonalignable differences than did Super-Midlevel (same) pairs, $t(16) = 3.02$, $p<.05$, and Super-Midlevel (different) pairs

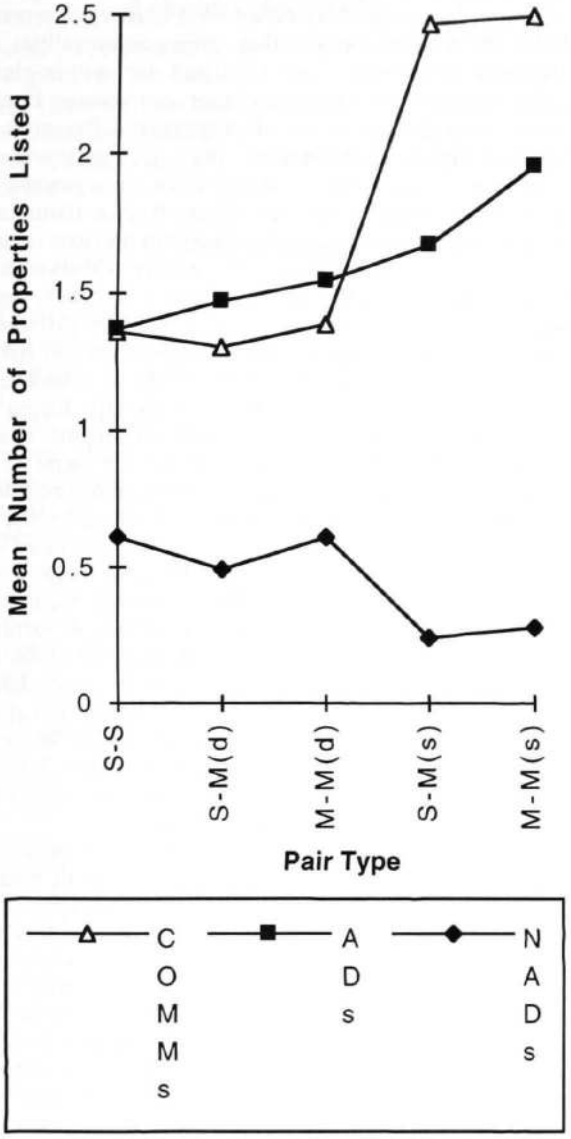

Figure 1: Graph of mean number of Commonalities, Alignable Differences and Nonalignable Differences listed in Experiment 1. In Pair Type, S stands for Superordinate and M stands for Midlevel.[4]

[4]For sticklers, this graph should be a bar graph, because pair type is not continuous. However, the pattern of data is easier to see this way, and so we have used a line graph here.

elicited more nonalignable differences than Super-Midlevel (same) pairs, $t(16) = 2.91$, $p<.05$. Both findings suggest that the mental representations of verbs from different clusters have very little in common, making it very difficult for them to be compared in a way that gives rise to commonalities and alignable differences. This finding is analogous to the one obtained for noun hierarchies (Markman & Wisniewski, 1997), further supporting a cluster view of verb organization.

The relative importance of alignable and nonalignable differences for comparisons within and between hierarchies can be seen in an analysis of the proportion of listed differences that were alignable differences. This analysis is shown in Table 2. A one way ANOVA on these data revealed significant differences between conditions, $F(4,49) = 4.43$, $p<.05$. Post-hoc analyses revealed that subjects listed significantly more alignable differences for Super-Midlevel (same) pairs than for Super-Super pairs, $t(16) = 2.89$, $p<.05$, and more alignable differences for Midlevel-Midlevel (same) pairs than for Super-Super pairs, $t(16) = 2.99$, $p<.05$.

Table 2: The means and standard deviations of , associations and proportions of alignable differences listed in the experiment.

Condition	Associations	Proportion of Alignable Differences
Super-Super	0.42 (0.25)	0.70 (0.14)
Super-Midlevel (different)	0.48 (0.31)	0.74 (0.10)
Midlevel-Midlevel (different)	0.34 (0.26)	0.72 (0.15)
Super-Midlevel (same)	0.08 (0.11)	0.86 (0.10)
Midlevel-Midlevel (same)	0.19 (0.28)	0.87 (0.10)

Previous research on similarity has suggested that people often confuse similarity and association. (Bassok & Medin, 1997). Consistent with that finding, people often listed associations between verbs. As shown in Table 2 that tendency was particularly prevalent for the pairs from different hierarchies.

The distribution of associations closely resembled the distribution of nonalignable differences. Subject listed significantly more associations for Super-Super pairs than for Super-Midlevel (same) pairs, $t(16) = 3.69$, $p<.01$, and more associations for Super-Midlevel (different) pairs than for Super-Midlevel (same) pairs, $t(16) = 3.60$, $p<.01$.

In summary, pairs of verbs from the same hierarchy yield significantly more commonalities than verbs from different hierarchies. The same pattern of data was evident for alignable differences, but the differences between conditions were not as large as they were for commonalities (a pattern that is also true of nouns). Finally, the opposite pattern was obtained for nonalignable differences and associations—few

were listed for pairs from the same hierarchy, and many were listed for pairs from different hierarchies.

Discussion

The results of this study are consistent with the idea that verbs are organized into hierarchies by troponymic relations.

The large number of commonalities and alignable differences that subjects listed for within hierarchy pairs indicate that those verbs share a common representational structure. In contrast, the large number of nonalignable differences and associations that subjects listed for between hierarchy comparisons, suggests that verbs from different hierarchies do not have a common representational structure, but rather that the representations of verbs from different hierarchies have structures that are not alignable. These results are consistent with data from nouns suggesting that nouns that are hyponyms of a common superordinate have similar representational structures and that nouns that come from different superordinates have nonalignable representational structures.

To demonstrate the strong consistency of the data with the predictions of the hierarchical view of verb organization, we examined the differences between conditions for which the hierarchical view made predictions. In particular, the hierarchical view predicts that every condition that involves two troponyms of the same superordinate or a superordinate and one of its troponyms should have (on average) more listed commonalities and alignable differences and fewer nonalignable differences than any condition involving verbs from different superordinates. There are six such comparisons for each dependent variable (commonalities, alignable differences and nonalignable differences) making a total of 18 comparisons. Consistent with the hierarchical view, all 18 of these comparisons are in the predicted direction. This pattern of data is inconsistent with what would be expected on a matrix view, which would predict no consistent differences between the within and across hierarchy pairs.

Further support for this conclusion comes from the results of another study in which we asked subjects to give similarity ratings for pairs of verbs. There, Super-Midlevel (same) pairs and Midlevel-Midlevel (same) pairs received significantly higher similarity ratings than Super-Super, Super-Midlevel (different), and Midlevel-Midlevel (different). pairs. Moreover, Super-Midlevel (same) were rated as significantly more similar than Midlevel-Midlevel (same) pairs, suggesting that Superordinate verbs may occupy more central positions within verb clusters. This finding is in agreement with results of research on semantic distance and semantic relations of concrete nouns (Rips, Shoben & Smith, 1973).

In addition to providing support for a hierarchical organization of verbs, data from the current study provided evidence that associations between words often enter into similarity tasks. Previous research has shown that similarity judgments can be affected by the presence of strong associations between words (Bassok & Medin, 1997). The results of the present studies suggest that associations are most likely to be listed for dissimilar pairs that have few commonalities. It is possible that similarity seeks some kind of relationship between a pair, favoring commonalities and differences over other relationships. In the absence of any good commonalities and alignable differences (or in the presence of particularly strong associations) associations may come to play a strong role in perceived similarity.

So far, we have interpreted that data as support for a hierarchically organized lexicon for verbs. However, we cannot rule out the possibility that verbs are not organized into strict hierarchies, but rather form clusters or semantic fields. Both views predict that more commonalities and alignable differences will be listed for within-cluster comparisons than for between-cluster comparisons. Further, both views predict more nonalignable differences for between-cluster comparisons than for within-cluster comparisons. Some indication that verbs are organized into clusters rather than hierarchies comes from a dissimilarity between the present results and those from previous research on taxonomic hierarchies in nouns (Markman & Wisniewski, 1997). In one study with noun pairs, people found it awkward and difficult to list the differences between nouns and their superordinates (e.g., to list the differences between a robin and a bird). In contrast, the participants in our study had no difficulty listing the differences of superordinates and their troponyms. Indeed, the results for these pairs were about the same as for comparisons of two troponyms of the same superordinate.

There is another difference between nouns and verbs that is evident from these data. On average, subjects listed only half as many commonalities and differences for verbs, compared to the results from Markman and Wisniewski (1997) study on nouns (see also Markman & Gentner, 1993). This finding is in agreement with the claim that nouns have a dense internal structure, whereas verbs have a relatively sparse one (Gentner, 1981). This proposal agrees with the finding that commonality and difference listings of abstract concepts (like honesty and trust), which probably have sparse internal representations, also give rise to few listed properties (Markman & Gentner, 1993).

Given that the commonality and difference listings on verbs did not yield many properties relative to what is obtained for comparisons of nouns, it is worth speculating about the role of comparison in verb acquisition and processing. For nouns, comparison seems to be an important operation. New nouns may be compared to existing nouns during acquisition. In contrast, comparison may be less central in the processing of verbs. The function of a verb in a sentence is to bind together the objects via external relational connections rather than focusing on relations that hold between properties of the verb itself. In contrast, nouns manifest many internal relational connections and few external relational connections (see also Gentner, 1981). Nonetheless, comparison is not irrelevant for verbs. Verbs often provide semantic contrasts with other verbs that could have been used in the same sentence. For example, the meaning of to jog is to run slowly. The contrasts suggested by these verbs may involve implicit comparisons.

In conclusion the methodology used in this study allowed us to gain insight into the structure of mental representations for verbs. This study supports the claim that verbs are organized into semantic clusters in which verbs within a

cluster have comparable representational structures. More work is required to determine whether verb organization is better described by a cluster view or a hierarchical view. This work must focus on tasks that are more sensitive to the dynamic aspects of lexical organization like sentence verification.

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