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Authors
Hidaka, Shohei
Maouene, Josita
Smith, Linda B.

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Josita Maouene (jcmaouene@indiana.edu)
Department of Psychological and Brain Sciences, 1101 E. Tenth Street
Bloomington, IN 47405 USA

Shohei Hidaka (hidaka@cog.ist.i.kyoto-u.ac.jp)
Graduate School of Informatics, Kyoto University;
Yoshida-Honmachi, Sakyo-ku, Kyoto, 606-8501, JAPAN

Linda B. Smith (smith4@indiana.edu)
Department of Psychological and Brain Sciences, 1101 E. Tenth Street
Bloomington, IN 47405 USA

Abstract

This paper reports a computational analysis of the semantic structure of the first 103 verbs typically learned by young speakers of English, relative to their relation to body parts. The results suggest that early verbs are strongly related to body parts, and tend to be organized to just four main body regions: mouth, eyes, legs, hands. The results also suggest that similarities among verbs in associated body parts may influence children's acquisitions of those verbs. The results fit with growing behavioral and neuro-imaging results on the role of the body – and sensory-motor interactions in the world – in verb meanings.

Keywords: developmental psychology, language acquisition, verb semantics, statistics.

What, if anything, does the morphology of the body have to do with word meanings? Common verbs –kissing, hugging, putting, holding – are very much about bodily interactions with the world. It seems likely that as young children learn these words they are often engaged in the labeled action – kissing or being kissed, for example – actions that saliently involving specific body parts such as the lips. This paper presents new evidence concerning the role of body parts in organizing early-learned verbs.

Body parts as a basis for verb meaning

Verbs are often considered to be the relational center of sentences and their semantics –and their acquisition – is often studied in terms of their relations to other words (e.g., Gentner, 1992; Gleitman, 1990). However, as L. Bloom (1972) has noted, children learn and use words because they are relevant to their own goals, desires and actions. From this perspective, early verb meanings might be expected to be embedded in the child's physical actions in the world, rather than merely in relations among words. Consistent with this idea are many studies suggesting early verb use is oftent in relation to the child's wants and actions (Braine, 1976; Huttenlocher, 1974; Tomasello, 1992). For example, in one Huttenlocher (1974) found that children both comprehended and produced words more when they were about their own actions rather than when they were about the actions of others. In brief, if children's own real time and physical actions are a source of emerging meanings, one might expect early verb meanings to be related to these physical actions and also to the body parts that execute them.

Recent behavioral and neuro-imaging studies of adults also suggest a close link between verb meanings and bodily actions. Performing an opposing action (e.g., pulling with one's hands when the verb is *push)* interferes with word recognition (e.g., Glenberg, Gutierrez, Levin, Japuntich, & Kaschak, 2004). Further in functional MRI studies, presentation of a verb has been shown to activate the specific motor areas involved in producing the action labeled by that verb (e.g., Hauk , Johnsrude & Pulvermuller, 2004). These adult verb meanings seem likely to have their developmental origins in children's sensori-motor interactions in the world and thus also point to the value of studying the relation between early verbs and body parts.

Finally, evidence from a variety of cross-linguistic studies suggests the utility of looking to body parts as organizers of semantic systems. Across the world's languages, body parts play a significant role in organizing concepts of number, space, measurement and emotion (deLeon, 1994; Saxe, 1981; Yu, 2004). The idea that bodily interactions organize verb semantics is also a centerpiece of cognitive linguistics (Talmy 1988; Clark, 1976). Accordingly, the present research sought preliminary evidence on the role of body parts in the semantic organization of a corpus of common verbs, the verbs normatively learned first by speakers of English.

Specific Goals

The research examined the first 103 verbs that typically comprise the first verbs acquired by speakers of English. The study was designed to answer four questions:

(1) Do English adult speakers consistently associate specific body parts with these common verbs ?
(2) Are only a few or many of these verbs systematically related to particular body parts?

(3) Can these verbs be organized in a semantic space well structured by body parts?
(4) Is the order of acquisition of these verbs related to body parts involved in the referred-to action?

Answering these questions is a first step to determining how verb meanings may be grounded in bodily action.

Method

The potential relevance of body parts to individual verbs was measured by providing adults with a list of verbs and asking them to supply *one* body part associated with each verb. The participants were not told the reasoning behind the task and they were *not* asked for the body part associated with action; instead participants were free to supply whatever body part popped into their heads for whatever reason. Our rationale in the use of this task is this: If early verbs are associated with bodily actions done by particular body parts - and this is shared knowledge by mature speakers of the language - then adults should (1) systematically associate specific body parts with specific verbs and (2) they should agree with each other. These judgments comprised the data set for the computational analyses.

Subjects

Indiana University; all were native speakers of English.

Stimuli

The verbs studied were the 101 out of a total of 103 action terms on the MacArthur Communicative Developmental Inventory (Fenson, Dale, Reznick & Bates, 1994). Data on two verbs *tear* and *stay* had to be removed for various errors. In addition we incorporated two verb *kneel and tiptoe* which our preliminary study on body parts had shown were understood by children this age and had the interesting characteristic of having the body part in their label (Maouene, 2005). This inventory was developed from a normative study of over 1000 16 to 30 month old children learning English and is widely used to measure individual children's productive vocabulary. The 103 verbs in the inventory are the most frequent verbs in the productive vocabulary of children learning English during this developmental period. There is also normative data on the proportion of children producing each verb at monthly intervals from 16 to 30 months, allowing us to determine the order of acquisition of verbs in this corpus. The earliest verb on this list (*go*) is known by 50% of the children at 19 months and the latest verb (*wish*) is not known by 50 % of the children until after 30 months.

Procedure

The participants were given a randomly ordered list of the 103 verbs and asked to supply the one body part that first came to mind when they thought of the verb. There were no constraints on the body part terms that participants could offer; they were free to supply any body part, at any level of scale - e.g., fingernails, fingers, hands, arms, whole body.

Analyses

From these judgments, we created a body-part vector for each verb. This vector represents the number of adult judgers who listed each body part as associated with the verb. Nested body parts (e.g., lip, mouth, head) were treated separately. For example, the "meaning" vector for *bite* has these values within it: 29 mouth, 19 teeth, 1 head, and 1 lip as these are the numbers of the 50 adults who gave each one body part when given the word *bite*.

Results

Sixty-two uniquely different body parts were offered by the participants as associates for these verbs. Figure 1 provides a matrix of the 103 verbs by 62 body parts. The darker the segments the higher the numbers of adults providing that body part. As is apparent from these data, there appears to be considerable agreement among adults and moreover, there seems to be several clusters of verbs, from left to right in the figure: a leg region, arm region, ear region, mouth region, and eye region.

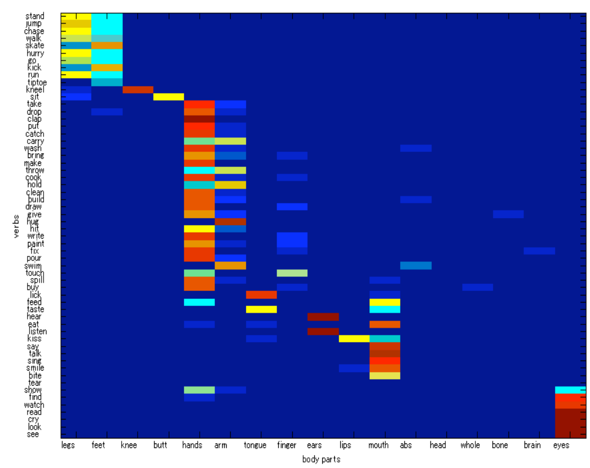

Figure 1: The partial data of the matrix verbs by body-parts.

1) Do English adult speakers consistently associate specific body parts with these verbs?

To answer this question, we calculated the entropy for each verb, where $P(B_b)$ was proportion of rating of *bo*th body parts to total ratings (100). The entropy of body parts was also calculated in the same way.

$$E_i = -\sum_{body \supset b} P(B_b) * \log(P(B_b))$$

Entropy is maximized when the rating of body parts is distributed uniformly randomly, thus ratings with smaller entropy indicate greater consistency in the adult judgments.

The maximum and minimum entropy for randomly selected verb vectors in a Monte Carlo simulation (N=10000) were 5.76 and 5.18.

Figure 2 shows a frequency histogram of the entropy for the 103 verbs. The mean and maximum entropy of all verbs were 1.47 (relative entropy: .255) and 3.35 (relative entropy: .581), considerably less than that given by the Monte Carlo simulation. These results thus indicate that the adult participants – despite the lack of any constraints on their judgments – agreed with each other about the body parts associated with each of these early-learned verbs.

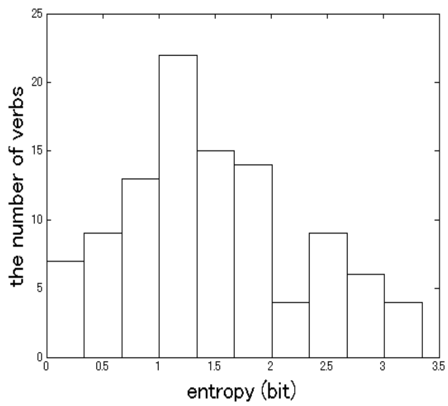

Figure 2: The histogram of the entropy of each verb.

2) Are only a few of these verbs systematically associated to particular body parts?

To address this question, we analyzed the multidimensional verb-body-parts (103 by 62 matrix) data with Correspondence Analysis, which is a kind of Principal Component Analysis for qualitative data. CA is not sensitive to variance (as is PCA) but to correlation, in this case between verbs and body parts. It does not need any external criterion (i.e. only data pattern is analyzed). The CA analysis indicated that 8 dimensions were needed to account for 60% of the associations, 10 for 70%, 13 for 88% and only 19 dimensions were needed to account for 90% of the judgment data provided by the participants. This constitutes a huge reduction from the 62 distinct body parts. Table 1 provides evidence on the particular body parts listed by participants, and those that were correlated with each of the dimensions yielded by the CA.

Table 1: The 8 dimensions according to CA.

Dim.	Corr.	Body parts (>S.D.)	Verbs (>S.D.)
1	0.9427	ears	hear, listen
2	0.8576	mouth, lips, teeth, tongue	bite, blow, drink, eat, feed, kiss, lick, say, sing, smile, talk, taste
3	0.7627	eyes, brain	cry, find, hide, look, read, see, show, sleep, wake, watch
4	0.7209	arm, hand, finger	bring, build, buy, catch, clap, clean, cook, draw, drop, fix, give, hit, make, paint, pour, put, spill, take, wash, write
−4	0.7209	eyes, tongue, leg, feet , toes	chase, cry, dance, find, go, hurry, jump, kick, lick, look, read, run, see, skate, stand, tiptoe, wake, walk
5	0.6573	kneel, tongue	kneel, lick, taste
6	0.6504	mouth, knee, heels	bite, blow, climb, drink, eat, kiss kneel, say, sing, smile, talk
7	0.5955	knee, toes	kneel, tiptoe
8	0.5166	eyes, hands	cry, find, look, read, see, show, watch

3) Can these verbs be organized in a semantic space well structured by body parts?

The CA also indicated a second reduction (from 19) to 4 if we leave aside the ear-verbs dimension, we have a four-arm-structure: mouth-verbs=-dimension1, eye-and-brain verbs=dimension2, arm-verbs =dimension 3 and leg-verbs=dimension4. This data compression strongly suggests that the corpus of verbs as a whole is systematically related to an organized set of body parts. The four-arm-structure correspond to verbs strongly associated with the legs, arms, mouth and eyes. Only a few verbs like *show* (involving hand and eye) and *feed* (involving mouth and hand) fall outside this organization. Ordering along the arms as shown in Figure 3 is related to the scale of body part involved (fingers versus hands, lips versus teeth) and the degree of exclusivity in that body part's association with the verb.

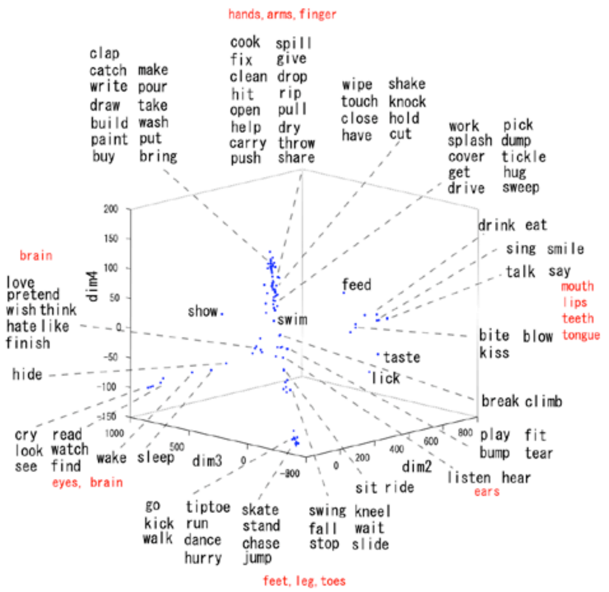

Figure 3: Correspondence analysis for dimensions 2,3,4 corresponding to a four-arm-structure.

4) Is acquisition structured by the relevant body parts?

To study the relation between age of acquisition and body parts, we used a time scale that aimed at capturing the developmental trajectory for each verb. Specifically, each verb's development was represented as a vector of the proportion of children typically producing that verb according to the normative data at monthly intervals from 16 to 30 months. The 101 verbs from MCDI were used to calculate city-block distance of acquisition rate (from 16 month to 30 month: a 15-dimension vector) and the city-block distance of adults' body parts rating (a 62-dimension vector) of every verb paired with every other verb (4950 pairs). The precise definition of verb pair difference of acquisition rate
α (normalized by division with 15 months) and body parts β (normalized by division with maximum difference 200: twice of the number of ratings), where A_{im} and B_{ib} are respectively *i* th verb's acquisition rate in *m*-month-olds and *b* th body parts rating.

$$Aq = 1/15 \sum_{verb \supset i,j} \sum_{month \supset m} \left| A_{im} - A_{jm} \right|$$

$$Bd = 1/200 \sum_{verb \supset i,j} \sum_{body \supset b} \left| B_{ib} - B_{jb} \right|$$

The histogram of the number of verb pairs is shown Figure 4. Further analysis revealed that the distribution of difference of acquisition rate given difference of body parts was a Poisson distribution.

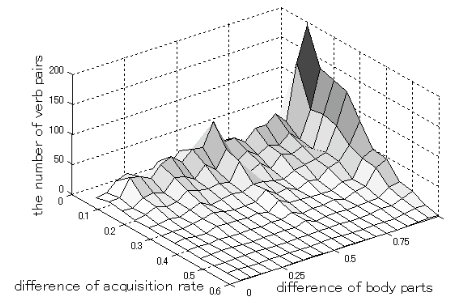

Figure 4: Histogram of the number of paired verbs along difference of acquisition rate and body parts.

Using 20 bins of difference of body part at even intervals (i.e. from 0 to 1 with .05 intervals), the correlation between the mean and variance was .920, and the proportionality constant and intercept of the linear regression were .630 ($t(18)=9.96$, $p<.001$) and .0005 ($t(18)=.530$, $p>.6$). We analyzed the mean of the distribution independent of variance (i.e., the interval between verb pairs) because the distribution could be considered as Poisson distribution. The correlation between the means of difference in acquisition rate of any two verbs and the difference in the body part vector of the two verbs was .692 (significant higher than zero correlation: $p<.001$).

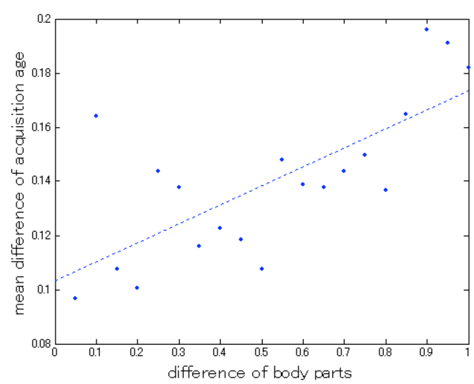

Figure 5: The scatter plot of difference of the body part vector for pairs of verbs and the difference in acquisition age.

As the previous analysis showed that the error distribution is Poisson distribution unlike normal distribution in regression analysis, we analyzed using Generalized Linear Model (GLM) with linear link function, Poisson distribution and the acquisition rate as dependent variables. The analysis showed the proportionality constant and intercept of the linear regression were .082 (t(5048)=4.21, p<.001) and .0095 (t(5048)=6.23, p<.001). As both coefficients were significant, the mean paired verb's difference in acquisition rate α and difference in body parts β is estimated as following the relationship. This indicates that 50% difference of adult rating predicts .62 month difference of verb acquisition on average.

$$\overline{Aq} = .082 \times \overline{Bd} + .0995$$

The key point is this: two verbs sharing that similar body part are acquired in similar period. This is evidence that the body-parts associated with individual verbs are related (in some as yet unspecified way) with the developmental ordering of verb acquisitions.

Given the analyses thus far, there are three reasonable hypotheses about how body parts might be related to order of acquisition.

•**Hypothesis 1:** The arms structure in Figure 3 orders acquisition such that, for example, mouth verbs are early and hand verbs are late.

•**Hypothesis 2:** Degree of pureness of body parts associated predicts age of acquisition. For example, the verbs that all adults associated with only one body part at the same scale are acquired first.

• **Hypothesis 3:** Children acquire unordered islands, but once they know a few verbs involving the same body parts, acquisition of other verbs involving that body part occurs.

Our analyses suggest the following conclusions:

First, the arms in Figure 3 only weakly organize the order of acquisition. Children learn at least some verbs on every arm at every point in development. This conclusion is supported by a one-way ANOVA to mean acquisition age (when over 50% children acquire each verb) of each verb categories ("ear", "mouth", "eye", "arm", "legs" shown in Table 1) showing no significant difference (F(4,56)=1.28, p=.29). However, other analyses (presented subsequently) suggest that mouth verbs constitute a greater proportion of early-learned verbs and hand verbs a greater proportion of later learned verbs.

Second, degree of pureness of "body part" also does not predict well the order of acquisition. We investigated the relationship between entropy and acquisition age (when over 50% children acquire the verb) to test the hypothesis that children learn earliest the verbs related to fewer body parts. The correlation of the two variables was .1587 (not significant difference to zero correlation, p=.1148, indicating that the verbs related to fewer body parts tended to be learned earlier.

Finally, there is data consistent with the Island hypothesis. Verbs that are close to other already acquired verbs in the body-part semantic space are acquired faster than those that are nearer fewer already acquired verbs.

In brief, these three hypotheses, (1) arms organize order, (2) degree of pureness –earliest verbs is purely related to one body part, (3) island, only (3) island (by analysis using Poisson distribution) was strongly supported, and (2) degree of divergence was weakly related to acquisition order.

Body maps

Figure 6 provides a holistic representation of the development of early verbs in terms of their associated body parts. These body maps were developed from the original body-map vectors constructed for each verb. The size of each "homunculus" indicates the total number of verbs known by 50% of children at the indicated age according to the normative MCDI data and the size of a constituent body part grows with the number of verbs associated with that body part. The smallest body map shows the verb meanings for a normative 21 month old. Normatively children this age have nine verbs in their productive vocabulary. Body maps for four subsequent ages are also shown: 22 months (21 verbs), 24 months (45 verbs), 26 months (74 verbs), and 30 months (96 verbs). The 5 remaining verbs (rip, pretend, think, wish, hate) were not included because they are acquired after 30 months of age. As is apparent, verb acquisitions are clustered by body part. At every age, children add new verbs related to all body parts but different body parts dominate earlier versus later acquisitions. At 21 months, verbs involving actions of the mouth and lip dominate accounting for 47% of the "meanings" of all verbs known at this age. Growth in verb meanings from 22 to 24 months overwhelmingly (86% of all new meanings) concerns actions by the limbs. The predominant region of growth after this point is in verbs that specifically involve the hands, counting for 58% of new meanings from 24 to 26 months and 59% of all new meanings from 26 to 30 months. At 30 months, verbs labeling actions involving hands and arms dominate all verb meanings, accounting for 51% of all verbs in children's total productive vocabulary at 30 months. Together, these body maps provide a developmental picture of verb learning that is strongly organized by the body's morphology.

Figure 6: These homunculi yield a perceptual representation of the development of the relative importance of parts in the acquisition of the first hundred verbs.

Conclusion

These results point to the importance of the body –and our bodily interactions in the world – in verb meaning and in the acquisition of verbs. Granted, these results are a first step; they show only that adults systematically relate body parts to early learned verbs. But the nature of that systematic relation is highly suggestive. Specifically, the results point to the following:

(1) Only a few body parts and regions matter –ears, eyes, mouth, legs and arms. These are the parts of the body with which one actively engages in the world and with others.
(2) For many early verbs, there is only one body region to which it is related. This suggests meanings that are grounded in specific concrete actions accomplished in specific ways, rather than highly abstract relations that may be done by any body part.
(3) Children's (normative) rate of acquisition of verbs appears related to the density of the body part region, suggesting again, that body parts organize developmentally relevant aspects of meaning.
(4) Verbs related to the mouth are important early although verbs related to the hands are the most frequent in the corpus as a whole and clearly dominate at later points in acquisition. This last fact raises interesting questions about the precise relation between kind of action, kind of body part, and verb meaning.

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