Polysemy in the Mental Lexicon

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The semantic ambiguity of lexical forms is pervasive: Many, if not most, words have multiple meanings. For example, one can *draw* a gun, *draw* water from a well, or *draw* a diagram. Despite the frequency of this phenomenon, how human beings store and access these meanings is an open question. Do we have a separate representation in our mental lexicon for each "sense," or do we store only one very generalized or core meaning for each word? If the latter, do we generate the nuances of each separate sense by rule or by accessing subrepresentations? To even speak of senses in this way implies that we can clearly identify the separate senses of a word. In this study, we use priming in a semantic decision task to investigate the effect of different levels of meaning relatedness on language processing. Both response time and accuracy followed a linear progression through four categories of meaning relatedness. These results suggest that the distinction between a single phonological form with unrelated meanings (homonyms) and a single form with related meanings (polysemes) may be more one of degree than of kind. They also imply that related word "senses" may be part of a continuum or cluster of meanings rather than discrete entities. In addition, results from specific comparisons between groups do not support the theory that each sense of a word has an entirely separate mental representation.

1. Introduction

Pinning down how people store and process words with multiple meanings has proven difficult to do, and the wide variety of theories currently in contention illustrates how little consensus has been reached. At one end of the spectrum lie theories in which each phonological form is connected to one complex semantic representation, with precise senses of a word only realized in context (Kintsch 2001, 2007; Ruhl 1989). In these theories, the unrelated meanings of homonyms coexist in the single semantic representation and are resolved in context by the surrounding words in the utterance. At the other end lies the theory that each sense of the same form, whether unrelated (homonyms) or related (polysemes),

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has its own semantic representation, with nothing but the phonological form in common (Klein & Murphy 2001).

In the middle of the spectrum lie several popular theories, all of which suggest that related senses share a general or core semantic representation. For some, this core is the only thing stored in long-term memory. Individual senses are generated online through some combination of pragmatics, general patterns of extension, and reasoning, given the context of the word (Nunberg 1979; Pustejovsky 1995). For others, individual senses may be stored, but related ones share a core representation or occupy overlapping areas of semantic space (Klepousniotou & Baum 2006; Pylkkänen, Llinás & Murphy 2006; Rodd, Gaskell & Marslen-Wilson 2002, 2004). These theories can be compared to many dictionaries, in which homonyms have separate entries but polysemes are listed as a single entry, with subentries for each sense.

Many researchers have investigated this question with lexical decision tasks, in which subjects decide whether a word they are seeing is a real word. Response times are thought to indicate how easily a subject has accessed the word. Several such studies were designed to compare homonymy and polysemy. Azuma and Van Orden (1997) used words rated for the number of their senses and the relatedness of the senses. They found that, after controlling for number of senses, words with related senses had faster reaction times than words with unrelated senses, suggesting that polysemy facilitated lexical access as compared to homonymy.

Other studies suggested that polysemous words are identified in lexical decision tasks more quickly than single-meaning words (Beretta, Fiorentino, & Poeppel, 2005; Klepousniotou 2002; Rodd, Gaskell, & Marslen-Wilson, 2002, 2004). In addition, Rodd, Gaskell and Marslen-Wilson (2002) found the opposite effect for homonyms; namely, that homonymy slows response times. These two effects, the authors argue, reflect different processing methods for homonyms and polysemes, which stem from different mental storage architectures. The slower response times for homonyms are attributed to competition between separate mental “entries” or representations, whereas the faster response times for polysemous words are attributed to the ease of accessing a single, broad mental representation.

A different pattern emerged, however, when subjects were forced to make judgments about meaning. Klein and Murphy (2001) used a “sensicality” decision task, in which subjects were asked to judge whether short phrases “made sense” or not. Subjects saw one phrase, such as “daily paper”, then saw another phrase with the same noun, either with the same meaning, “liberal paper”, or with a different meaning, “lined paper”. (Nonsense foils, such as “angry plate”, were interspersed with the target pairs.) The authors found that with this task, reaction time differences between homonyms and polysemes disappeared. That is, after processing one meaning of a word, the processing of another related meaning was inhibited rather than facilitated, compared to processing the same meaning again. The inhibition resulting from unrelated meanings (homonyms) was not reliably different from that from related meanings. Klein and Murphy conclude that every sense of a word, related or unrelated, must have a separate mental representation, with no shared core meaning between them.

Pylkkänen et al. (2006) used a similar semantic judgment task for homonyms, polysemes, and semantically related separate words. While subjects performed the task, the authors used the neuroimaging technique magnetoencephalography (MEG) to look for any differences in brain activation between the homonym condition and the polyseme condition. The response time results were similar to those in the Klein and Murphy (2001) study. However, MEG measurements taken during the task found brain activation differences between homonyms and polysemes in both the left and right hemispheres, especially as compared to semantically related separate words. In the left hemisphere, polysemes elicited shorter M350 latencies, which has been hypothesized to index lexical activation. Conversely, simultaneous activity in the right hemisphere peaked later for sense-related than for unrelated targets, which the authors suggest may be caused by competition between related senses. Furthermore, they propose that these patterns of activation could result from separate mental representations for homonyms, but a single representation for a polysemous word, with separate subrepresentations for the related senses.

In trying to discover the shape of our mental lexicon, these researchers have focused on comparing homonyms and polysemes. Their materials have primarily consisted of nouns, with individual items falling fairly cleanly into one of those categories. However, in order to test those theories that postulate a clear distinction between homonyms and polysemes, one must look at the border between those two categories.

Verbs are in general more complex than nouns since they perform the task of relating various other items in an utterance. They often have numerous senses. In fact, the more frequent a verb is, the more senses it is likely to have, with some verbs listed in dictionaries with 50+ senses. For this reason, verbs provide an excellent arena for examining the mental representation of word meaning.

Verbs may provide us with some insight into whether there is a sharp distinction between meanings that are related and those that aren’t. The Oxford English Dictionary (2002) lists the senses of *draw* in ‘he drew his gun’ and ‘he drew a picture’ as related, although most people would see these as unrelated. Historically, the sense in ‘drew a picture’ developed from the sense in ‘he drew a line in the sand’, itself from ‘he drew the stick through the sand.’ These senses are distantly related to senses of pulling, such as ‘the ox drew the cart,’ which are related to senses of pulling toward, as in ‘he drew the cup toward him’ or extraction, ‘he drew the gun.’ The overlaps in meaning with this verb are quite complex, and it is difficult to say which would have separate mental representations and which would not. In addition, some senses that may have been seen as related by the average person at some point in the past would now be seen as homonyms, with no shared meaning whatsoever.

Similarly, those theories that advocate separate mental representations for each word sense, related or unrelated, must look at the border between one sense and two distinct senses. For example, WordNet (2005) considers the senses of *draw* in the following sentences as separate.

1. He drew a knife during the fight.
2. He drew a gun during the fight.
3. He drew a card from the pack.
4. He drew water from the well.

Would all of these have separate mental representations? Would the representations of *draw* in the following two senses be different as well?

5. He drew his Colt .45.
6. He drew his Smith and Wesson .22.

Many scholars (Hanks 2000; Kilgariff 1997; Krishnamurthy & Nicholls 2000) have discussed the difficulty in determining which usages represent the same sense and which different senses.

Assuming this problem could be solved, a theory of word meaning that assumes different senses are represented separately would predict quite different behavior for recall of same-sense usages (recall of a single mental representation) versus different-sense usages (recall of distinct mental representations). In addition, this theory would predict that accessing closely related senses would be just as difficult as accessing distantly related senses or unrelated senses. If polysemes and homonyms have the same storage and method of processing, degree of meaning relatedness should have no effect on response times or accuracy. If they each have a separate representation, they should behave similarly.

Understanding how people connect form and meaning is fundamental to understanding language processing and has implications for lexicography, foreign language learning, and computer processing of natural language. In order to discover the nature of these connections, we must look at the full range of meaning relatedness for a single word or form. In this study, we investigated meaning relatedness by looking at the facility with which people move between senses of a word. Given the rich meaning nuances of verbs, we focused on this lexical category, choosing verb senses with varying degrees of relatedness, from homonymy through to nearly indistinguishable senses.

2. Method

2.1. Participants

Participants were native English speakers over the age of 18. One group of 20 participated in the preparation of materials, and another group of 33 acted as subjects in the judgment task.

2.2. Materials

Four groups of materials were prepared, each consisting of 11 pairs of phrases. Each phrase in a pair contained the same verb. The groups comprised (1) homonymy, (2) distantly related senses, (3) closely related senses, and (4) same senses (see Table 1 for examples). Placement in these groups depended both on the classification of the usages by the lexical resources WordNet and the Oxford English Dictionary and on the ratings given to pairs of phrases by a group of undergraduates. The raters placed the relatedness of the verb senses in each pair on a scale of 0 to 3, with 0 being completely unrelated and 3 being the same sense.

A pair was considered to represent the same sense if the usage of the verb in both phrases was categorized by WordNet as the same and if raters gave the pair an average rating greater than 2.7 (condition avg. 2.87). Closely related senses were listed as separate senses by WordNet and received a rating between 1.8 and 2.5 (avg. 2.26). Distantly related senses were listed as separate senses by WordNet and received ratings between 0.7 and 1.3 (avg. 0.92). Because WordNet makes no distinction between related and unrelated senses, the Oxford English Dictionary was used to classify homonyms. Homonyms were listed as such by the OED and received ratings under 0.3 (avg. 0.26). Interestingly, pairs that the OED considered as having related senses were often seen as homonyms by the raters. Although this phenomenon pertains directly to the questions addressed here, we eliminated these pairs to maintain the clarity of the categories.

As much as possible, arguments of the verbs were chosen to have minimal semantic overlap within pairs. For example, in the same sense condition, *broke the window* would be paired with *broke the plate* rather than *broke the glass* so that the objects were not from the same semantic field. In addition, phrases were placed in past tense in order to avoid the implication of an imperative in some of the phrases (e.g., *break the glass!*).

Table 1: Stimuli.

	Prime	Target
Unrelated	banked the plane	banked the money
Distantly related	ran the track	ran the shop
Closely related	broke the glass	broke the radio
Same sense	cleaned the shirt	cleaned the cup

The stimuli from these four conditions were balanced and randomized with pairs containing semantically anomalous, or "nonsense" phrases. These nonsense pairs contained either two nonsense phrases with the same verb (e.g., *hugged the juice/hugged the fund*) or one semantically coherent phrase and one semantically anomalous phrase (e.g., coherent then anomalous: *scared the fox/scared the dash,* or anomalous then coherent: *joined the cliff/joined the team*).

2.3. Procedure

We used a one-way repeated measures design in which every subject saw all 11 pairs in each of the four levels of relatedness. The stimuli from the four levels and the anomalous foils were randomized for each subject.

Subjects viewed the materials on a computer screen connected to buttons for *yes* and *no*. Subjects were instructed to press the *yes* button when a phrase was semantically coherent, or "made sense," and to press *no* when the phrase was semantically anomalous, or "difficult to make sense of." They were instructed to answer as quickly but as accurately as possible. A phrase appeared on the screen and remained in view until the subject responded *yes* or *no*. After a 300 ms pause, the next phrase appeared. Participants responded to all phrases, both prime and target. Both response time and accuracy were measured for target phrases. Because all target phrases were semantically coherent, the correct response to these phrases was always "yes." Accuracy was measured as the percentage of target phrases receiving a "yes" response. Although participants responded to the "nonsense" pairs, response times and accuracy for these phrases were not included in the analysis, as these pairs did not constitute one of the conditions of study. They were included as foils to the test pairs to encourage participants to fully access the meaning of all phrases.

3. Results

The following results are based on one-way ANOVAs using planned, orthogonal contrasts. Response times differed significantly between the groups ($F_{3,30}=18.4$; $p<.0001$), as did accuracy ($F_{3,30}=50.5$; $p<.0001$). More focused contrasts reveal interesting facilitation or inhibition effects among the groups.

When comparing response times between same sense pairs and different sense pairs (all the other conditions, including closely related, distantly related, and unrelated conditions), we found a reliable difference (same sense mean: 1056ms vs. different sense mean: 1272ms; t_{32} =6.33; $p=.0002$). We also found better accuracy for same sense pairs (same sense mean: 95.6% correct vs. different sense mean: 78%; $t_{32}=7.49$; $p<.0001$). When moving from one phrase to another with the same meaning, subjects were faster and more accurate than when moving to a phrase with a different sense of the verb, whether that sense was related to the first or not.

Moving between closely related senses also proved quicker and more accurate than moving between distantly and unrelated senses. Closely related sense response times were reliably faster than the mean of distantly related and unrelated pairs (t_{32}=5.85; p<.0005), and accuracy was higher (t_{32}=8.65; p<.0001).

A distinction between distantly related pairs and homonyms was found as well. Response times for distantly related pairs was faster than for homonyms (distantly related mean: 1253ms, homonym mean: 1406ms; t_{32}=2.38; p<.0001). Accuracy was enhanced as well for this group (distantly related mean: 81%, unrelated mean: 62%; t_{32}=5.66; p<.0001). In this case, polysemy did seem to facilitate access to meaning when compared to homonymy.

A final planned comparison tested for a linear progression from completely unrelated senses, through distantly related senses, then closely related senses to same senses. Although somewhat redundant with the other comparisons, this test did reveal a highly significant linear progression for response time ($F_{1,32}$=95.8; p<.0001) and especially for accuracy ($F_{1,32}$=100.1; p<.0001). These results show a smooth progression, with response time fastest for same sense pairs and then increasing at a regular rate as meaning relatedness decreased. Accuracy decreased at a regular rate as meaning relatedness decreased.

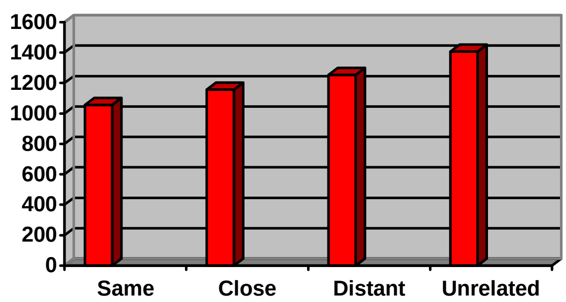

Figure 1: Mean response time (ms).

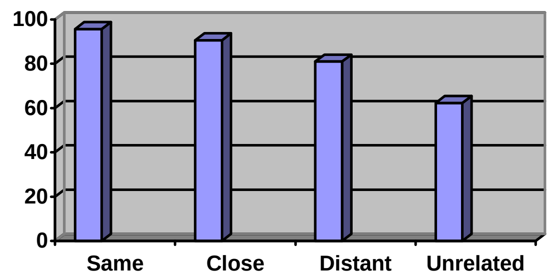

Figure 2: Mean accuracy (% correct).

4. Discussion

The results have implications for various theories of lexical storage and processing, which I will address in turn. The theory that all senses have separate representations, with polysemes and homonyms represented in the same way, receives its strongest support from the comparison of same sense pairs to different sense pairs. This theory would predict this to be a fundamental distinction, with same sense pairs strongly facilitated compared to all different sense pairs. The confirmation of this, however, does not eliminate a theory in which related senses share a core representation. Such a theory would be entirely compatible with this result.

The separate representation theory also predicts that response time and accuracy for closely related pairs should be similar to distantly related pairs and unrelated pairs. If they all have separate representations, access to meaning should proceed in the same way for all. For example, if one is primed with the phrase ‘fixed the radio,’ response time and accuracy should be the same whether the target is ‘fixed the vase’ or ‘fixed the date.’ We found, however, a significant difference between these two groups, with closely related pairs accessed more quickly and accurately than the distantly related and unrelated pairs.

A direct comparison of response times for homonyms and distantly related polysemes revealed a facilitory effect for the polysemes. The increased accuracy and faster response times indicate that moving between one sense and a distantly related sense is easier in some way than moving between two unrelated senses. This suggests some sort of difference in representation between polysemes and homonyms, an implication contrary to the separate representation theory.

Our results are more compatible with shared representation or “single entry” theories, but not conclusively so. These theories postulate a fundamental difference between homonyms and polysemes. Unrelated senses (homonyms) are seen as having distinct semantic representations or “entries” in the mental lexicon. Related senses (polysemes) are seen as sharing a portion of a semantic representation, with nuances of meaning diverging from that shared portion. This sort of structure is also described as one “entry” for a polysemous word, with “subentries” for different related senses.

As stated above, the fact that the meanings of same sense pairs were accessed more quickly and accurately than the meaning of different sense pairs is compatible with this theory. One would expect accessing a single “entry” or full representation to be easier than accessing different “subentries” of a single “entry” or accessing different extensions of a core sense.

The strongest support for this theory, however, comes from the significant difference between distantly related senses and homonyms. If homonyms have completely separate representations, one would expect them to be accessed more slowly and less accurately than senses that share a core representation or “entry,” and this is indeed what we found. This finding in particular calls into question the separate representations theory while supporting a shared representation or "single entry" theory.

The discovery of a linear progression among the groups tested suggests a slight alteration or extension of the "single entry" theory. A linear progression could fit with this theory if, in addition to polysemes being housed in different subentries of a single representation, we picture subentries of subentries, or a hierarchy of sense distinctions. In this way, people might access closely related senses more quickly than distantly related senses. They would have a shorter distance to travel in the hierarchy, so to speak, or have less of an already activated semantic representation to overcome.

In this case, however, postulating a qualitatively different representation between polysemes and homonyms is less appealing. Homonyms show a similar degree of inhibition to distantly related senses as distantly related senses do to closely related, which suggests that the difference between homonyms and polysemes is only a matter of degree, not of kind. In addition, when people rated the phrase pairs for how related the verb senses were, there was a definite lack of consensus on which senses were distantly related and which were completely unrelated. This supports the notion that the distinction between homonyms and polysemes may not be so clear-cut.

Nevertheless, there may indeed be a fundamental difference between polysemes and homonyms, with different causes for the similar degree of inhibition we saw between groups. The variations in brain activation found by Pylkkänen et al. (2006) seem to support the theory that there is a basic difference between polysemes and homonyms. It would be interesting to see if there is further variation in right and left hemisphere activation when polysemes of different degrees of relatedness are tested.

The linear progression through meaning relatedness is also compatible with a theory in which the semantic representations of polysemes overlap. Rather than polysemes being discrete entities attached to a main "entry", they could share a general semantic space. Various portions of the space could be activated depending on the context in which the word occurs. This structure allows for more coarse-grained or more fine-grained distinctions to be made, depending on the needs of the moment.

5. Conclusion

The results of this study refine our understanding of the connection between form and meaning. Often a single form is used to represent multiple meanings. These meanings can be semantically unrelated or show different degrees of relatedness. Several theories have been proposed as to how people store and process the meanings of these words. One theory holds that every sense of a word has a separate semantic representation in the mental lexicon. Another influential theory holds that related meanings share a portion of their semantic representation, whereas unrelated meanings have separate representations.

These theories have been primarily tested by comparing differences in processing time between noun homonyms and polysemes. We used a semantic judgment task to assess the ease with which people move between senses with four degrees of meaning relatedness. In addition, we used verbs rather than nouns because of the variability of verb meaning when the item is placed in context with different arguments.

We found that priming differences between the conditions do not support a theory in which each meaning connected to a form has a separate mental representation. Such a theory would predict no difference in semantic processing time when moving from one sense to another that is related or one that is unrelated. However, we found significant differences in processing time and accuracy between processing related meanings and unrelated meanings. Even distantly related meanings were processed more quickly and accurately than unrelated meanings.

Theories that postulate separate representations for homonyms and single but subdivided representations for polysemes were compatible with our findings. In addition, the significant linear progression through meaning relatedness that we found most strongly supports theories in which related meanings share varying portions of their semantic representation, or in which related meanings overlap in semantic space. One can imagine varying portions of shared meaning among different degrees of relatedness. Closely related senses could share a large portion of their semantic representations, while distantly related senses would have minimally overlapping representations. The sharing of semantic representations may dwindle until no semantic overlap remains, as in the case of homonyms. As we saw with the verb *draw*, there may be a sequence of meaning relations that one can trace from “they drew close to the fire” to “they drew water from the well” without the connection being obvious when looking at just those two utterances.

This sort of structure is compatible with cognitive linguistics theories of family resemblances and fuzzy boundaries in word meaning and concepts (Lakoff 1987; Rosch 1975). These theories reject the notion that a category can be defined with necessary and sufficient conditions. Instead, members of a category (and polysemes can be seen as members of a category) can be more or less prototypical of the category. Also, the boundaries between categories can be fuzzy or indeterminate. Several analyses have been done of polysemous words that demonstrate these qualities of overlap, extension, and fuzzy boundaries among the words’ senses (Brugman 1981).

A structure in which the semantic representations overlap allows for the apparently smooth progression from same sense usages to more and more distantly related usages of a word. It also provides a simple explanation for semantically underdetermined usages of a word, a pervasive phenomenon we have not yet addressed. Although separate senses of a word can be identified in different contexts, in some contexts, both senses (or a vague meaning indeterminate between the two) seem to be represented by the same word. For example, "newspaper" can refer to a physical object: "He tore the newspaper in half," or to the content of a publication: "The newspaper made me mad today, suggesting that our committee is corrupt." The sentence "I really like this newspaper" makes no commitment either way. One can equally well imagine the following sentence to be "It has nice large print," or "It always covers local events."

Linguists have attempted to discriminate varying degrees of ambiguity in lexical items (Cruse 1986) and to develop criteria for determining when ambiguity indicates either simple vagueness or different senses. Geeraerts (1993) revealed the inconsistency and unreliability of such tests, suggesting that a sharp distinction between vagueness and distinct senses may not exist. A theory of semantic representations that allows for overlapping representations or shared core representations helps explain this phenomenon. When encountering a word, one can simply access the core representation or activate the center of the semantic space, and only access further nuances if it is necessary.

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