

The Number and Relatedness of a Word's Meanings in a Lexical Decision Task

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Abstract: Past lexical decision studies investigating the number and relatedness of meanings effect have produced mixed results. In the present experiment, we selected 20 ambiguous words and 12 non-words, and asked 30 English major students to judge whether they were real words or not, and then recorded their reaction time. In lexical decision tasks, relatedness (high or low), NOM (many or few), and nonword condition were manipulated. After an analysis of variance, we find that the NOM effect is significant but no significant effect of relatedness was observed in the experiment. The results show that the number of a word's meanings can influence lexical decision performance.

Keywords: NOM; RT; Relatedness of Meanings.

1. Introduction

Words in English vary greatly with respect to their numbers of meanings (hereafter NOM). For example, the word DRAW has at least six common meanings, but the word POND has only one.

Numerous studies have assessed the effect of NOM on performance in simple reading tasks (Balota, Ferraro, & Connor, 1991). Some lexical decision experiments have reported that words with many meanings are recognized faster than words with few meanings (Kellas, Ferraro, & Simpson, 1988; Millis & Button, 1989). This NOM effect has also been observed in naming (Balota, Ferraro, & Connor, 1991). The NOM effect is usually explained by assuming local, discrete memory structures that are selected probabilistically. For example, it is commonly assumed that word identification entails lexical entries or nodes which mediate access to conceptual memory (Forster & Chambers, 1973). The NOM effect makes sense if a probability advantage is assumed for words with more nodes (Raab, 1962).

The ambiguity advantage can also be applied to Chinese. In a lexical decision experiment with Chinese nouns in which ambiguous nouns with homonymic and/or metaphorical meanings were contrasted with unambiguous nouns, an ambiguity advantage effect was also obtained—Chinese nouns with multiple meanings were recognized faster than those with only one meaning. The results suggested that both homonymic and metaphorical meanings are psychologically salient semantic levels actively represented in the mental lexicon. (Lin, C.J.C., Ahrens, K., 2010).

Although participants can correctly categorize letter strings as words faster if they have multiple meanings (i.e., ambiguous words) than if they have one meaning (i.e., unambiguous words) when performing a lexical decision task, when reading connected text, participants tend to fixate longer on ambiguous words than on unambiguous words (Piercey, C.D., & Joordens, S., 2000).

On the other hand, the predictions for a relatedness effect are more straightforward. The inherent structure of most distributed models leads to a reduction of the predicted importance of NOM and a stronger emphasis on relatedness of meanings. It is clear that English word meanings vary in

their degrees of semantic relatedness. Traditionally, words with more than one meaning can be seen as a ambiguous word. Ambiguity between unrelated meanings is known as homonymy, where two words happen to share the same orthography and phonology. An example is the word BANK, which can be the side of a river or a financial institution. How homonymy comes about (historical relations or accidental coincidence of orthography and phonology) is of no consequence to models of lexical access. Ambiguity between related senses is known as polysemy. Consider the word DOOR in the following sentences.

- (1) The door fell off its hinges.
- (2) The child ran through the door.

The sense of DOOR in (1) is clearly different from the sense of DOOR in (2). In (1), DOOR is a physical object, whereas in (2), it is an aperture. As a further example, let us take another look at the homonymous word BANK. One of its meanings (financial institution) can be seen to possess different polysemous senses:

- (3) The bank apologized to its customers.
- (4) The bank was destroyed in an earthquake.

In (3), BANK is an institution; in (4), a building.

So ambiguous words can be either homonymous or polysemous, and it is also possible for one or more meanings of homonyms to be polysemous. In addition, the number of polysemous senses a word may have can vary a great deal.

The importance of relatedness is most clear in accounts in which recurrent feedback self-organizes the model's behavior (Plaut & Shallice, 1993). Covariant learning discovers the covariation across words' various meanings and surface forms (Orden, G. C. V. et al., 1990). A word with related meanings exhibits stronger correlations between its surface form and overlapping "pockets" of meaning, relative to a word with an equal number of unrelated meanings. In a model with recurrent feedback, these pockets become strong attractors that pull the system toward a coherent state congruent with a "word" response (Plaut & Shallice, 1993).

In one experiment on Japanese Katakana words, the relatedness of meanings had an effect when Kanji words and nonwords were included. Participants may have used the relatedness of activated meanings as a cue, artificially creating a relatedness advantage for Katakana words.

However, in another experiment, when the Kanji nonwords consisted of characters with similar (i.e., related) meanings, there was no relatedness effect for Katakana words (Hino, Y. et al., 2010). These results challenge the idea that the speed of semantic coding is influenced by the relatedness of meanings for ambiguous words.

Importantly, in the study of Haro, J. et al., no differences were found between homonyms and polysemous words, on either N400 amplitudes or in RTs. Their result suggests that ambiguous words, regardless of the relatedness between their meanings, benefit from enhanced semantic activation in comparison to unambiguous words during word recognition (Haro, J. et al., 2017). Therefore, lexical decision studies investigating the relatedness of meanings effect have produced mixed results as well.

The present study aims primarily to test the NOM and relatedness effects. If there is a NOM effect, then many-meaning ambiguous words were responded to faster than few-meaning ones. Likewise, if there is a relatedness effect, then high-related ambiguous words were responded to faster than low-related ones. To this end, the design and stimulus materials of Orden, G. C. V., & Azuma, T. (1997) were chosen for our study.

2. Experiment Methods

The following experiments contrast NOM×Relatedness in a factorial design. These can be orthogonally manipulated because they are not fully correlated with each other. In this experiment, the effects of NOM and relatedness on lexical decision performance were addressed.

2.1. Participants

30 undergraduate students majoring in English at Hangzhou Normal University participated in the experiment. All participants had passed TEM-4 and had normal or corrected-to-normal vision.

2.2. Stimulus Materials

20 ambiguous words and 12 legal nonwords were selected to be included in the experiment. Within these ambiguous words, there are four conditions, i.e. few/low condition (e.g. calf, pound), few/high condition (e.g. trap, faint), many/low condition (e.g. slip, strip), many/high condition (e.g. blank, lock), with five words selected for each condition. All these words were taken from Appendix A of Orden, G. C. V., & Azuma, T. (1997).

The number of different meanings supplied for each word was determined as follows: each provided meaning was matched to an entry in Webster's New World Dictionary. If multiple meanings corresponded to the same entry, only one meaning was counted. Meanings that couldn't be matched to any dictionary entry were excluded. Only 19 out of approximately 12,000 responses couldn't be matched. The experimenter then counted the number of different meanings for each word. To test reliability, a second judge repeated the procedure for 22 randomly selected words, and inter-rater reliability was found to be 0.95. Words with six or more meanings were classified as many-meaning, while words with four or fewer meanings were classified as few-meaning.

In a similar way, the mean relatedness rating for each meaning pair was calculated. A psychologically valid metric of relatedness developed by Durkin and Manning is deployed, also based on participants' judgments of meaning relatedness. Only words that produced more than one meaning were

selected for evaluation of meaning relatedness. For each word, the dominant meaning was determined; all remaining meanings were considered subordinate. The dominant meaning was then paired with each subordinate meaning and presented with a seven-point rating scale as follows:

BANK

1. A financial institution
2. The land alongside a river

Relatedness:

Not Related 1 . . 2 . . 3 . . 4 . . 5 . . 6 . . 7 Very Related

A word's total relatedness score was defined as the mean relatedness rating of all of its meaning pairs. Words with relatedness scores less than 3.0 were classified as low-related, and words with relatedness scores more than 3.5 were classified as high-related.

In addition to the stimulus manipulations of NOM and relatedness, a between-participant manipulation of nonword type was also included in the experiment. A set of words, which did not overlap the stimulus words, was used to construct the legal nonwords. The legal nonwords were four or five letters long.



Figure 1. Screenshot of the Start Interface of the Experiment

2.3. Procedure

Participants were tested individually. At the beginning of the experiment, participants were instructed in the lexical decision task. They had to react to each word that appeared and decide if it was a real English word. All participants were instructed to respond as quickly and accurately as possible.

The technology for the experiment was constructed using Compleat Lexical Tutor website [22]. The website is primarily for data-driven language learning with many functional modules, such as online corpus search, creating cloze questions, etc. Among these functional modules, we chose the reaction time module. After the participants typed the arrow-down key and started the experiment, 32 randomly ordered stimulus words were presented one after another. At the beginning of each trial, a fixation stimulus ("wait...") was presented in the center of the screen and in the approximate center of the forthcoming letter string. The participants were instructed to press a "YES" key with their right index finger if the letter string was a word, and a "NO" key with their left index finger otherwise as shown in the figure 1. (the arrow-left and arrow-right keys respectively on a standard keyboard). After 500 ms, a stimulus item replaced the fixation stimulus

and remained on the screen for two seconds, or until the participant responded. Feedback on accuracy and reaction times was provided after each trial.

2.4. Analysis

Reaction times were measured from the onset of the visual stimulus until button press. After the experiment was done, we exported the RT data from the website. Incorrect responses and responses longer than 2 seconds were removed from analysis. Incorrect responses resulted in 5.83% of the data points (35 data points) being removed from the analysis. In total, incorrect and overly slow responses resulted in the loss of 14% of the data (84 data points).

3. Results and Discussion

Mean values of response time and accuracy were calculated across participants and items. The mean response time and error rates for each of the four stimulus conditions is given in Table 1.

Table 1. Mean Reaction Times(in ms) and Error Rates

Degrees of relatedness	Number of meanings	
	Few	Many
High RT	994	936.6
Error rate	6.67%	2%
Low RT	993.6	944.9
Error rate	11.33%	4%

An analysis of variance was performed on the RTs of correct answers by setting NOM and meaning relatedness respectively as x variables (independent variables), as shown in table 2 and table 3 correspondingly. According to table 2, the main effect of NOM was significant. Responses were faster to many-meaning words (940.75 ms) than to few-meaning words (993.8 ms).

Table 2. ANOVA Result of NOM and Mean RT

	NOM(average±standard deviation)		F	p
	few(n=10)	many(n=10)		
Mean RT	993.80±61.73	940.75±50.90	4.396	0.050

* p<0.05 ** p<0.01

Evidently, the results of the present experiment replicate those studies that have shown that multiple-meaning words are recognized more rapidly than are those with only one meaning. That is to say, multiple-meaning words allow better performance on a lexical decision task than do words possessing only one meaning.

Lexical access involves an initial shallow stage of semantic access followed by a post-lexical selection stage. At the initial stage of word recognition (as required by lexical decision experiments), the processor aims at retrieving just one semantic node or a portion of the semantic representation to recognize a stimulus string as a word. At this stage, semantic access need not be exhaustive. The ambiguity advantage effect found in our lexical decision studies can be accounted for by this shallow level of incomplete semantic access.

Two possible explanations can be proposed to account for this early effect. According to a probability-based model of random lexical access, words with multiple meanings have more semantic nodes randomly distributed across the

semantic space (Rubenstein et al. 1970). Thus, ambiguous words stand higher chances of retrieval. A second possibility is that ambiguous words create a "blend state", which makes them easier to get at than unambiguous words (Piercey & Joordens, 2000). As suggested by classic studies of lexical ambiguity, all or at least most of the meanings associated with a word are initially activated (Ahrens et al., 1998; Ahrens, 1999; Onifer & Swinney, 1981). This initial activation of all associated meanings creates a semantic cluster that gives ambiguous words an edge for shallow semantic access. The ambiguity advantage found in lexical decision tasks thus can be taken as resulting from the easier access to any of its associated semantic nodes or the semantic blend state. The multiple semantic nodes associated with an ambiguous word do not compete with one another at this initial stage of lexical access as we observed no inhibition on ambiguous words.

At a subsequent stage, depending on what the task requires, a certain meaning needs to be selected to fit into a sentential context or to be compared with other meanings and/or other members of a semantic category. Lexical ambiguity at this stage produces a disadvantage as selection is costly and multiple meanings associated with a word may compete to be selected, therefore producing inhibition and difficulty in processing. That explains why while lexical ambiguity produced an advantage for word recognition in lexical decision tasks, it results in a disadvantage (incurring longer reading times) when the ambiguous words were presented in sentences.

From table 3, we can see that the main effect of relatedness was not significant, which indicate that the relatedness of a word's meanings may not particularly interfere with the primary task of lexical decision. Mean RTs to high and low-related words differed by only 4ms. High-related words (965.3 ms) resulted in somewhat faster responses than low-related words (969.25 ms). Within few-meaning words, mean RTs to high- and low-related words differed by only 0.4 ms. In this experiment, RTs to few/low and few/high words were slower than RTs to words in any other condition.

Table 3. ANOVA Result of Meaning Relatedness and Mean RT

	Relatedness(average±standard deviation)		F	p
	high(n=10)	low(n=10)		
Mean RT	965.30±68.10	969.25±57.61	0.020	0.890

* p<0.05 ** p<0.01

In the present experiment, although high-related words (965.3 ms) indeed resulted in faster responses than low-related words (969.25 ms), the relatedness effect was not significant. Concerning this result, it is worth noting that whereas several investigators claimed that high-related ambiguous words were responded to faster than low-related ones, other also have failed to obtain a relatedness effect. One possible reason for the inconsistency of these results may be the different approach employed to the categorization of ambiguous words across studies. In the present study, as well as in those where no significant differences were found between both types of ambiguous words, homonyms and polysemous words were categorized according to subjective measures. This represents a crucial methodological difference with respect to those studies showing that relatedness affects word processing, given that they mainly relied on dictionary definitions to classify the words. Such an approach is based

on the assumption that unrelated meanings are listed in separate dictionary entries, whereas related meanings are listed under the same dictionary entry. Within this approach, homonyms are taken to be words with more than one dictionary entry, whereas polysemous words are words having many dictionary senses within a single entry. Although more research is needed to compare directly the experimental effects of using these two distinct criteria, an interesting finding is that subjective measures of semantic ambiguity seem to be better predictors of lexical decision times than dictionary measures (Fraga, I., Padrón, I., Perea, M., Comesaña, M., 2017).

Another possible explanation for the null relatedness effect is that lexical decision is a task that does not engage very much semantic processing. Indeed, there is some evidence showing that ambiguous word processing may be modulated by the requirements of the experimental task. For instance, in contrast to the ambiguity advantage commonly found in lexical decision tasks, ambiguous words are usually responded to more slowly than unambiguous words in more semantically engaging tasks, such as semantic categorization, sense judgement and semantic relatedness tasks as mentioned before. These tasks, unlike lexical decision tasks, usually require a specific meaning of the ambiguous word to be activated. Consequently, not only will ambiguity have disadvantages, but significant relatedness effect will also be observed in these tasks. For example, Brown (2008) reported that pairs of homonym verb phrases (e.g. banked the plane – blanked the money) were responded to more slowly than pairs of polysemous verb phrases (e.g. broke the glass – broke the radio) in a sense judgment task. So, this evidence, although limited, suggests that relatedness effects may emerge in tasks requiring exhaustive semantic activation.

It is likely that both types of ambiguous words are represented similarly, that is, with each homonym or polysemous meaning having a separate entry in the mental lexicon. Thus, if each separate meaning of a homonym or polysemous word provides an independent stream of feedback to its linked orthographic representation, both types of ambiguous words would trigger a similar amount of semantic feedback and, thus, no differences should be expected between them in lexical decision tasks (Hino et al., 2010).

4. Conclusion

The manuscript should include a conclusion. In this section, summarize what was described in your paper. Future directions may also be included in this section. Authors are strongly encouraged not to reference multiple figures or tables in the conclusion; these should be referenced in the body of the paper.

To sum up, the experiment produced an NOM effect and we have presented evidence that number of meanings of a word can influence lexical decision performance and lexical ambiguity can facilitate the recognition of English words in lexical decisions. Regarding the role of semantic information in lexical access, different experimental tasks require different degrees of semantic access, reflecting the different stages of lexical and post-lexical access. Lexical decision tasks require only partial access to the whole semantic representation. Words with multiple meanings are therefore recognized faster as the semantic nodes associated with an ambiguous word form larger semantic clusters and are therefore easier (and more likely) to be accessed.

The NOM effect in the experiment has two important implications. Firstly, the present results may provide a bridge between NOM effects and the vast literature on NOM effects. The second implication involves theories and methods of future research in this area: Words with the same relatedness of meanings (hyponymous and polysemous words) should not be indiscriminately grouped together.

In addition, we have observed no differences between homonyms and polysemous words in reaction time data. This seems to indicate that relatedness does not affect ambiguous word recognition in lexical decision tasks, and that both types of ambiguous words benefit from triggering a similar amount of semantic activation.

A direction for future research would be to determine whether the total-meanings metric or the average-meanings metric is the better measure of accessible polysemy. Consider the situation in which one subject records two meanings for the word BOMB (e.g., an explosive device; to destroy), and a second subject records two different meanings for that word (e.g., a failure; a long pass in football). The total-meanings metric would estimate the word as having four accessible meanings, whereas the average-meanings metric would estimate the word as having two meanings. Now, consider the situation in which one subject records two meanings for the word SUIT (e.g., a formal outfit; a suit charged against someone), and a second subject reports the same two meanings. Both the total-meanings and the average-meanings metrics would estimate SUIT as having two accessible meanings. To determine which metric is the better measure of accessible polysemy, the lexical decision times to the words BOMB and SUIT could be directly compared. If the total-meanings metric is the appropriate measure to use, then reaction time should be quicker to the word BOMB than to the word SUIT, because it has more meanings. On the other hand, if the average-meanings metric is appropriate, then the reaction time for the two words should not differ because they have the same number of meanings. This possibility can be tested in the future.

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