Semantic Competition and the Ambiguity Disadvantage

Jennifer Rodd (jenni.rodd@mrc-cbu.cam.ac.uk)

Gareth Gaskell (gareth.gaskell@mrc-cbu.cam.ac.uk)

William Marslen-Wilson (william.marslen-wilson@mrc-cbu.cam.ac.uk)

MRC Cognition and Brain Sciences Unit
15 Chaucer Road, Cambridge, UK

Abstract

In many recent models of word recognition, words compete to activate distributed semantic representations. Reports of faster visual lexical decisions for ambiguous words compared with unambiguous words are problematic for such models; why does increased semantic competition between different meanings not slow the recognition of ambiguous words? This study challenges these findings by showing that visual lexical decisions to ambiguous words whose meanings were judged to be unrelated were *slower* than either unambiguous words or ambiguous words whose meanings were judged to be related. We suggest that previous reports of an ambiguity advantage are due to the use of ambiguous words with highly related meanings.

Introduction

Many recent connectionist models of written and spoken word recognition use distributed lexical representations; words are represented as a pattern of activation across a set of units. In most of these models, words are represented at an explicitly semantic level (Gaskell & Marslen-Wilson, 1997; Hinton & Shallice, 1991; Joordens & Besner, 1994; Plaut, 1997). Words compete for activation of these semantic representations, and for a word to be recognised, it must produce a familiar pattern of semantic activation. This paper reviews the existing evidence for such semantic competition effects, and reports a visual lexical decision experiment that suggests that semantic competition does play an important role in visual word recognition.

Ambiguous Words

One situation where semantic competition will occur is the case of ambiguous words. Homographs such as *bank* are words where a single orthographic form has more that one meaning. In the above models, the orthographic pattern *bank* must be associated with two different semantic patterns of activation corresponding to its two meanings. When the orthographic pattern is presented to a network model, these two semantic patterns will both be partially activated as the network tries to simultaneously instantiate both patterns across the semantic units. The likely consequence of this is that the two patterns of activation will interfere with each other, and delay the recognition of the word. This prediction of a processing disadvantage for ambiguous words is an example of the more general principle that one-to-one mappings are more easily learned and processed than mappings where a single input pattern corresponds to more than one output pattern. (For a review of such efforts see Joordens & Besner, 1994.)

However, there have been several attempts to show that, given the right assumptions, this class of model can show the opposite effect, an advantage for ambiguous words. The approach taken by Joordens and Besner (1994) relies on the assumption that when the orthography of a word is presented to the network, the initial state of the semantic units is randomly determined. Further, the closer to its target state the network starts, the quicker it will settle into that state. For ambiguous words, there is more than one valid finishing state, and the network is likely to settle into the target state closest to its initial state. On average, the initial state of the network will be closer to one of these states than for an unambiguous word where there is only one valid finishing state. Their network did show an ambiguity advantage, but only when the error rate was unrealistically high.

Kawamoto, Farrar, and Kello (1994) took a different approach to modelling an ambiguity advantage. They assumed that lexical decisions are made on the basis of orthographic, not semantic, representations. Using the least mean square (LMS) algorithm during training, an ambiguity advantage was shown. This arises because of the error-correcting nature of the learning algorithm; in order to compensate for the increased error produced by the ambiguous words in the semantic units, stronger connections are formed between the orthographic units, which are being used as the index of performance.

Therefore, successful demonstration of an ambiguity advantage relies on the assumption that the lexical decision task is primarily orthographic. This assumption has problems in accounting for the range of semantic effects on lexical decision. The simulations reported by Joordens and Besner (1994) make it clear that if the activation of the semantic units is used to model lexical decision in such networks, semantic competition makes it difficult for such networks to produce an ambiguity advantage.

Joordens and Besner (1994) argue that for this class of model "increased competition must occur when an ambiguous word is processed and that this competition must act to reduce processing efficiency". This gives us a testable prediction of models where words compete for activation of semantic representations: semantic competition should act to slow the recognition of ambiguous words relative to words with only one meaning.

The second semantic competition prediction relies on the observation that within the class of ambiguous words there are words that differ widely in the relatedness of their meanings. The linguistic literature has distinguished between two types of ambiguity: homonymy and polysemy. Traditionally homonyms are said to be different words that happen to have the same form, whereas a polysemous word is a single word that has more than one sense (Lyons, 1977). For example, the orthographic form *bank* is assumed to be a homograph, and to and correspond to two separate lexical items that share the same orthography purely by chance. Conversely, the use of the word *mouth* to describe the entrance to a cave as well as a part of the body is assumed to reflect the fact that *mouth* is a word with more than one sense (Lyons, 1977). This distinction between word senses and word meanings is respected by all standard dictionaries; lexicographers decide whether different usages of the same orthography correspond to different lexical entries or different senses within a single entry.

However, while this homonymy/polysemy distinction is easy to formulate, it is difficult to apply with consistency and reliability. There is not always a clear distinction between these two types of ambiguity, and people will often disagree about whether two word meanings are sufficiently related to be classed as senses of a single meaning. Despite this, it is important to remember that words that are described as ambiguous can vary between these two extremes.

This distinction is important when looking at the issue of semantic competition. Models in which words compete for activation of distributed semantic representations predict that recognition of ambiguous words will be slowed by competition between semantic representations. However, as noted by Rueckl (1995), competition between two meanings can be reduced by increasing the similarity of their representations. This means that the situation is different for ambiguous words with semantically related senses. Often these senses relate to a single core literal meaning of the word (Lyons, 1977). For such words there will be a high level of overlap between the competing semantic representations, and so the interference between them will be greatly reduced. We predict that this reduction in interference will result in ambiguous words being recognised faster when their different meanings are related than when they are highly unrelated. This is a second testable prediction of models where words compete for activation of distributed semantic representations.

The following two sections will review the literature that is relevant to these two predictions. We will then go on to report a lexical decision experiment that supports these two predictions.

The Ambiguity Advantage

The first prediction, that semantic competition will slow recognition of ambiguous words, is apparently contradicted by the available experimental evidence. The *ambiguity advantage* is the reported finding that words with many meanings are responded to *faster* in visual lexical decision experiments than words with fewer meanings. Therefore, rather than semantic competition slowing recognition of ambiguous words, there appears to be a processing advantage for such words.

Early reports of an ambiguity advantage (e.g. Rubenstein, Garfield, & Millikan, 1970) have been criticised for not controlling for subjective familiarity; words with more than one meaning are typically more familiar. Since then, Kellas, Ferraro, and Simpson (1988) report faster lexical decision times for ambiguous words than for unambiguous words, but they do not show that this effect reaches statistical significance. Hino and Lupker (1996) and Borowsky and Masson (1996) also report finding an ambiguity advantage in a lexical decision experiment, but the effect of ambiguity was not significant in the items analysis in either study.

Millis and Button (1989) and Azuma and Van Orden (1997) do show a statistically significant advantage in visual lexical decision experiments for words with many meanings when compared with words with few meanings. However, both these studies used procedures that counted highly related word meanings that correspond to different senses of a single dictionary entry as distinct meanings. For example, Millis and Button (1989) provide the word *tell* as an example of a word that has many meanings. Participants produced up to four meanings for this word; these meanings were: *to inform, to explain, to understand* and *to relate in detail*. Although there are important differences between these four definitions, they all relate to a single core meaning of the word, and are given as different senses within a single entry in the Wordsmyth Dictionary (Parks, Ray, & Bland, 1998).

Further, neither study compared ambiguous words with words with only one meaning. Rather, they compared words with few meanings with words with many meanings. This had the result that many of the low-ambiguity stimuli were themselves highly ambiguous, e.g. *spoke, staff, bark* and *seal* which all have more than one entry in the Wordsmyth Dictionary. We carried out an analysis of the stimuli used in the two experiments, and found that in both experiments, the low- and high-ambiguity words did not differ in their number of different dictionary entries; both groups had a similar number of words with multiple entries in the Wordsmyth Dictionary. Instead, the groups differed in their number of dictionary *senses*, with the high-ambiguity words having far more senses. This suggests that the ambiguity advantage they found was not the result of a benefit for ambiguity of the kind seen in the word *bank*, between two highly unrelated meanings. Rather, they have shown a benefit for ambiguous words that, in addition to any unrelated meanings, have clusters of related word senses.

As discussed earlier, ambiguity between related word senses would not necessarily produce the kind of semantic competition that we would expect for unrelated word meanings. For a reported ambiguity advantage to be problematic for models that incorporate semantic competition, the high-ambiguity words must have fewer semantically unrelated meanings than the low-ambiguity words. We believe that neither of these studies has shown such an effect. Therefore, the question of what effect the presence of semantically unrelated meanings has on word recognition has not yet been resolved.

Relatedness of Word Meanings

Two studies have investigated whether the relationship between the meanings of an ambiguous word can affect its recognition. Azuma and Van Orden (1997) report that for homographs with two to four meanings, visual lexical decision times are slower when their meanings were rated as being unrelated. This is consistent with our prediction that when the meanings of an ambiguous word are highly unrelated, there is greater competition between their semantic representations, and that this increased competition produces slower lexical decision times than when the meanings are highly related. However, as mentioned earlier, the procedure used by Azuma and Van Orden (1997) means that highly related word senses were counted as separate meanings. They were comparing words like *hide* and *park*, whose meanings are completely unrelated with words like *drink* and *rake* which are ambiguous only in that they can be used as either a noun or a verb. It is not clear that words with such highly related meanings should really be considered ambiguous. This study will attempt to replicate their finding using stimuli with greater ambiguity. We will compare words like *cricket*, whose meanings are semantically unrelated, to words like *letter*. *Letter* has two meanings, but they are semantically related in that they both refer to written language.

The second relevant experiment was performed by Rubenstein et al. (1970). They investigated the effects of ambiguity and concreteness on visual lexical decision times, and report faster lexical decision times for homographs with one concrete meaning and one abstract meaning than for homographs with two concrete meanings. If we accept that concreteness is an important semantic dimension, we would expect that on average two concrete meanings will be more similar than one concrete meaning and one abstract meaning. This makes Rubenstein et al.'s (1970) result somewhat counterintuitive; the homographs with less similar meanings were responded to faster. This is inconsistent with the finding of Azuma and Van Orden (1997), and conflicts with the view that increased competition between semantically dissimilar homographs should slow their recognition.

Therefore the two reports in the literature of semantic competition effects give somewhat contradictory findings. The experiment reported here attempts to resolve the issue. Its starting point is the design used by Rubenstein et al. (1970), since this is a result that is problematic for all classes of models.

Aims of the Experiment

The visual lexical decision experiment reported here has three main aims.

Firstly it will investigate the effect of ambiguity on word recognition by comparing words that have more that one meaning with words that are not ambiguous. Evidence of a disadvantage for ambiguous words would contradict previous reports of an ambiguity advantage, but support our first prediction, that semantic competition will slow recognition of ambiguous words. To avoid the problems associated with earlier studies, it will directly compare ambiguous words with unambiguous words that have only one dictionary entry. The ambiguous words will have two meanings with a range of relatedness.

The experiment will also address the prediction of that any slowing of the recognition of ambiguous words will be greater when the ambiguity is between meanings that are semantically highly unrelated. It will use a design that will allow us to investigate the finding by Rubenstein et al. (1970) that ambiguous words were responded to faster when they had one abstract and one concrete meanings than when both meanings are concrete. Finally, it will also look for direct effects of meaning relatedness.

Lexical Decision Experiment

Experimental Design A summary of the experimental design is given in Table 1. Three groups of homographs are used. Group CC contains homographs with two concrete meanings, homographs in Group CA have one concrete meaning and one abstract meaning, and Group AA contains homographs with two abstract meanings. The control stimuli are two groups of non-homographs. Group C consists of concrete non-homographs, matched for concreteness with the more concrete meaning of the homograph Groups CC and CA. Group A consists of abstract words, matched for concreteness with the abstract meanings of the words in Group CA.

Table 1: Experimental Design

	Homographs			Non-Homographs	
Group	CC	CA	AA	C	A
Example	calf	seal	lean	goat	sane

In addition to these between-group comparisons, it was intended to use correlation analyses to investigate the effects of the concreteness and relatedness of the two meanings of the homographs. To increase the number of words in this analysis all homographs that were pre-tested but eliminated during the matching of the groups were also included in the experiment.

Method

Stimuli The main selection criterion for the homographs was that they should have only two meanings. 130 homographs taken from a range of homograph norms were pre-tested to obtain ratings for the concreteness of each of their two meanings, and for their overall familiarity. Two groups of subjects not included in the lexical decision experiment made the familiarity and concreteness ratings, on a 7-point scale. The pre-tested stimuli were assigned to the five stimulus groups according to these concreteness scores. Concrete meanings had a minimum concreteness rating of 5.22; abstract meanings had a maximum concreteness of 4.96.

The five groups each contained 30 words, and were matched for length, frequency, familiarity, and neighbourhood density. The frequency measure used was the log-transformed frequency of the word in the spoken section of the British National Corpus (LnBNC). The neighbourhood density measure was the number of words in CELEX that differed from each word by only one letter.

These five groups can be collapsed to give a group of homographs (N=90) and a group of non-homographs (N=60); these two groups were also matched on all the above variables, as well as for mean concreteness. For a homograph, Mean Concreteness was the mean of the concreteness rating for its two meanings; for non-homographs it was simply the concreteness score for the word.

Thirty four homographs that had been pre-tested but were not included in one of the five groups were included in the experiment.

The non-word stimuli were pseudohomophones with a similar distribution of word lengths to the word stimuli.

Procedure The participants were 25 members of the MRC Cognition and Brain Sciences Unit subject panel. All the stimulus items were pseudo-randomly divided into four groups which participants saw in a pseudo-random order such that no two participants saw the lists in the same order. Within the lists, the order in which stimulus items were presented was randomised for each participant. All the participants saw all of the stimulus materials. The participants' task was to decide whether each item was a word or a non-word. Once a participant had responded, the next stimulus appeared after 500 ms.

Results

The latencies for responses to the word and non-word stimuli were recorded, and the inverse of these response times (1/RT) were used in the analyses.

ANOVA Analyses Mean values were calculated separately across subjects and items. The subject means were subjected to an analysis of variance (ANOVA), and the item means were subjected to an analysis of covariance (ANCOVA) with frequency, familiarity and length entered as covariates.

Incorrect responses were not included in the analysis. All responses greater than two seconds were also removed from the analysis; participants made between zero and six such responses, nearly all on the non-words; in total, only two such responses were made for the real words. The overall error rate for responses was 5.5%.

Response latencies for each cell of the design, averaged over subjects and items, are presented in Figure 1.

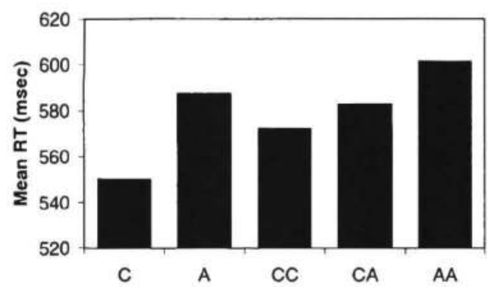

Figure 1: Mean lexical decision times

The analyses of variance using the five groups of words revealed a main effect of stimulus type, $F_s(4,88) = 13.27$, $p < .001$, $F_i(4,142) = 6.47$, $p < .001$. Multiple comparisons were made between the individual groups using the Newman–Keuls procedure.

For the non-homographs, there was a significant effect of concreteness, with response times for concrete words being significantly shorter than for abstract words; $q_s(3,88) = 7.39, p < .001$, $q_i(4,144) = 4.99, p < .001$.

For the homographs, although there was a trend towards faster responses for the more concrete groups, there were no significant differences between the groups of homographs.

In order to look at the effect of ambiguity, the three groups of ambiguous words (Groups AA, CA and CC) were collapsed and compared with the unambiguous words (Groups A and C). In the items analyses frequency, familiarity, length and mean concreteness were entered as covariates. The analyses revealed that the ambiguous words were responded to more slowly than the unambiguous words. The 16.5 ms difference was significant in both the subjects and the items analyses; $F_s(1,23) = 21.88, p < .001$, $F_i(1,144) = 4.93$, $p < .05$.

Analyses of the error data showed a similar pattern to the response time data: slower responses patterned with more errors.

Correlation Analyses The inverse response times for the homographs were also entered in a simple correlation analysis. Included in this were the 90 homographs used in the ANOVA analyses, as well as the 35 additional homographs.

Frequency (*LnBNC*) significantly predicted response times; $p < .001, r = .54$. Familiarity also significantly predicted response times; $p < .001, r = .48$. Partial correlations demonstrated that familiarity did not account for a significant proportion of variance in response times, when frequency effects were partialled out; $p > .3$. Frequency remained a significant predictor when familiarity was partialled out; $r = .31, p < .001$.

Three concreteness-related measures were entered in a correlation analysis of the inverse response times to the homographs in which frequency effects were partialled out: *mean concreteness*, *concreteness difference* and *dominant concreteness*. *Mean concreteness* is the average of the two concreteness scores, and *concreteness difference* is the difference between them. *Dominant concreteness* is the concreteness rating for the more dominant meaning of each homograph; the dominant meaning was determined on the basis of the frequency norms from which the homographs were taken.

Significant correlations were obtained between response times and *mean concreteness* $r = .20$, $p < .05$. This indicates a reliable effect of the concreteness trend, which was non-significant in the ANOVA analyses. The correlations between *concreteness difference*, *dominant concreteness* and response times were not significant.

Discussion

Three interesting results have emerged from this experiment.

Firstly, both the homographs and non-homographs showed a significant effect of concreteness; concrete words were responded to faster than abstract words. This serves as a useful replication of the concreteness effect, using stimuli that were controlled for subjective familiarity as well as frequency.

Secondly, the difference between the groups of homographs reported by Rubenstein et al. (1970) is likely to have been an artefact of their poorly-controlled stimuli. They reported that the homographs with two concrete meanings were responded to more slowly than those with one concrete meaning and one abstract meaning. We found the opposite effect, although this difference was non-significant.

Finally, and most importantly, response times showed an *ambiguity disadvantage*. Using stimuli that are matched for frequency, familiarity, length and orthographic neighbourhood, we have found an ambiguity disadvantage; words with one meaning were responded to significantly *faster* than words with two meanings. This apparently contradicts previous findings of an advantage for ambiguous words on visual lexical decision tasks.

In this experiment we used concreteness as the semantic dimension along which the words varied. This was in response to the finding of Rubenstein et al. (1970). The finding that concreteness difference had no significant effect on response times means that we have no evidence that homographs are recognised faster when their meanings have similar concreteness scores. Therefore, this analysis of the experiment provides no evidence that the relationship between the semantics of the different meanings of ambiguous words affects their recognition.

However, concreteness is only one aspect of the semantic properties of a word; comparing the concreteness of a word's meanings is a rather indirect way of measuring the semantic relationship between its different meanings. The following analyses will address the issue of the semantic relationship between the meanings of ambiguous words, by focusing more directly on semantic similarity. Using participants' judgements of how related the meanings of ambiguous words are, we will look for an effect of relatedness of lexical decision times.

Relatedness Ratings Analysis of Lexical Decision Experiment

Method

Relatedness ratings were obtained for 124 of the homographs used in the lexical decision experiment. Raters were given each homograph, together with short definitions of its two meanings, and asked to rate how related the two meanings were, on a 7-point scale.

Results and Discussion

The mean relatedness rating across all participants and items was 2.64. This low value reflects the fact that participants saw many of the pairs as completely unrelated; a rating of 1 was used more than any other rating. In all the following analyses, rather than using the mean relatedness ratings, the inverse of these values was used. This made the measure more sensitive to small changes at the lower end of the scale.

Correlation Analyses The relatedness values for the homographs were entered into a correlation analysis with the other predictor values used in the earlier analysis. Relatedness was not significantly correlated with frequency ($r = -.14, p = .13$), familiarity ($r = -.16, p = .07$), or mean concreteness ($r = .07, p = .48$). The only variable that relatedness was correlated with was *concreteness difference*, the difference between the concreteness values of the two meanings; $r = .24, p < .01$. This shows that the difference between the concreteness of the two meanings is moderately related to the overall relatedness of the meanings.

The real question of interest is whether the relatedness scores for the homographs significantly predict the lexical decision times. In a correlation analysis in which the effects of frequency, mean concreteness and concreteness difference were partialled out, relatedness was a significant predictor of response times ($r = -.19, p < .05$); homographs were responded to faster when their meanings were judged to be semantically related.

ANOVA Analyses To provide further evidence for the effects of relatedness, ANOVA/ANCOVA analyses were also performed. From the set of 124 homographs, two sets of 27 homographs were selected, containing related and unrelated homographs respectively. They were selected by using only those homographs with a relatedness score of either less than 1.9 or greater than 3.4. A few homographs were then removed so that the two groups were matched for frequency, mean concreteness, length, familiarity and neighbourhood density. A group of 43 non-homographs was selected to match the two homograph groups according to the same variables. The response times for these three groups of words were submitted to ANOVA/ANCOVA analyses. The mean response times are given in Figure 2.

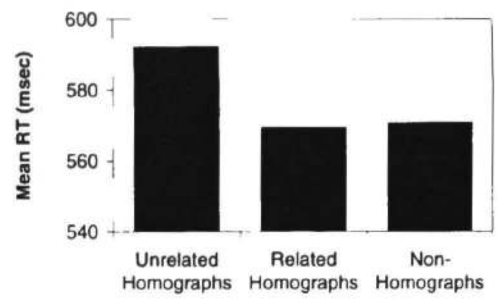

Figure 2: Mean lexical decision times

In the subjects analysis, the effect of group was significant; $F_s(2,44) = 6.74$, $p < .003$. In the items analysis, using the log-transformed frequency, familiarity, mean concreteness and length as covariates, the effect of group was marginal; $F_i(2,90) = 2.80, p < .07$.

Multiple comparisons were made between the individual groups, using the Newman–Keuls procedure. Responses to the group of non-homographs were faster than to the group of homographs with unrelated meanings; this difference was significant in the subjects analysis and marginal in the items analysis; $q_s(3,44) = 4.89, p < .005$, $q_i(3,90) = 3.23, p < .06$. The related homographs were significantly faster than the unrelated homographs in the subjects analysis; again, the difference was marginal in the items analysis; $q_s(2,44) = 3.95, p < .01$, $q_i(2,90) = 2.72, p < .06$

These results confirm the findings of the regression analysis; homographs with related meanings are responded to more quickly than homographs with highly unrelated meanings. Further, they show that homographs are responded to more slowly than non-homographs only when their meanings are unrelated.

In summary, post-hoc analyses using relatedness ratings for the homographs used in the lexical decision experiment times were performed using regression and ANOVA analyses. These showed that responses were quicker for homographs with related meanings (e.g. *letter*) than for those with unrelated meanings(e.g. *cricket*). This result fits well with the idea that words compete at a semantic level of representation, and that recognition of the homographs with unrelated meanings is slowed by increased competition between the competing semantic representations.

General Discussion

The lexical decision experiment reported here confirms predictions made by models of visual word recognition where words compete to activate distributed semantic representations and are recognised as familiar patterns of activation. Homographs with two meanings were responded to more slowly than unambiguous words; we found a significant ambiguity *disadvantage* for a group of 90 homographs, compared with 60 non-homographs that were controlled for frequency, familiarity, length, neighbourhood size, and concreteness. This difference completely disappeared for ambiguous words whose two meanings were judged to be semantically related. These findings are explained by assuming that recognition of an ambiguous word is slowed by competition between the semantic representations corresponding to its different meanings. This semantic competition arises only for words whose different meanings are highly unrelated.

The finding of a disadvantage for ambiguous words clearly contradicts previous reports of an ambiguity advantage. We have suggested that this apparent discrepancy may be explained by noting that all the studies that report a reliable ambiguity advantage count highly related senses as distinct word meanings. Their findings can therefore be explained as a benefit for words with clusters of related meanings rather that a benefit for ambiguity.

Reports of an ambiguity advantage have presented a serious problem for models where words are recognised as familiar patterns of semantic activation, and there have been several attempts to model the effect using such models (Joordens & Besner, 1994; Kawamoto et al., 1994). We have argued that the ambiguity advantage is an artefact of the way in which ambiguous words have been selected for experiments. The significant *disadvantage* we found for ambiguous words is a result straightforwardly predicted by this type of model.

The lexical decision experiment reported here provides important evidence that processes of semantic competition are crucially involved in word recognition, and supports the trend in the literature towards models where semantic representations actively participate in word recognition.

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