The Advantages and Disadvantages of Semantic Ambiguity

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Abstract

There have been several reports of faster lexical decisions for words that have many meanings (e.g., *ring*) compared with words with few meanings (e.g., *hotel*). However, it is not clear whether this advantage for ambiguous words arises because they have multiple unrelated meanings, or because they have a large number of highly related word senses. All current accounts of the ambiguity advantage assume that it is unrelated meanings that produce the processing benefit. We report two experiments that challenge this assumption; in visual and auditory lexical decision experiments we found that while multiple senses did produce faster responses, multiple meanings produced a disadvantage. We discuss how models of word recognition could accommodate this new pattern of results.

Introduction

Many words are semantically ambiguous, and can refer to more than one concept. For example, *bark* can refer either to a part of a tree, or to the sound made by a dog. To understand such words, we must disambiguate between these different interpretations, normally on the basis of the context in which the word occurs. However, ambiguous words can also be recognised in isolation; when presented with a word like *bark* we are able to identify an appropriate meaning rapidly, and are often unaware of any other meanings.

Words can be ambiguous in different ways. The two meanings of a word like *bark* are semantically unrelated, and seem to share the same written and spoken form purely by chance. Other words are ambiguous between highly related senses, which are systematically related to each other. For example, the word *twist* can refer to a bend in a road, an unexpected ending to a story, a type of dance, and other related concepts.

The linguistic literature makes a distinction between these two types of ambiguity, and refers to them as homonymy and polysemy (Lyons, 1977; Cruse, 1986). Homonyms, such as the two meanings of *bark*, are said to be different words that by chance share the same orthographic and phonological form. On the other hand, a polysemous word like *twist* is considered to be a single word that has more than one sense.

All standard dictionaries respect this distinction between word meanings and word senses; lexicographers routinely decide whether different usages of the same spelling should correspond to different lexical entries or different senses within a single entry. Many criteria (e.g., etymological, semantic and syntactic) have been suggested to operationalise this distinction between senses and meanings. However, it is generally agreed that while the distinction appears easy to formulate, it is difficult, to apply with consistency and reliability. People will often disagree about whether two usages of a word are sufficiently related that they should be taken as senses of a single meaning rather than different meanings. This suggests that these two types of ambiguity may be best viewed as the end points on a continuum. However, even if there is not a clear distinction between these two different types of ambiguity, it is important to remember that words that are described as ambiguous can vary between these two extremes.

In this paper we will review the evidence on how lexical ambiguity affects the recognition of isolated words, and will argue that the distinction been these two qualitatively different types of ambiguity has not been addressed. We then report two experiments that confirm the importance of the sense-meaning distinction, and show that in both the visual and the auditory domains the effects of word meanings and word senses are very different.

The Ambiguity Advantage

In early studies of semantic ambiguity, Rubenstein, Garfield, and Millikan (1970) and Jastrzembski (1981) reported faster visual lexical decisions for semantically ambiguous words than for unambiguous words. However, these studies did not control for the subjective familiarity of the words, and Gernsbacher (1984) found no effect of ambiguity over and above familiarity. Since then, however, Kellas, Ferraro, and Simpson (1988), Borowsky and Masson (1996) and Azuma and Van Orden (1997) have all reported an ambiguity advantage in visual lexical decision experiments using stimuli that were controlled for familiarity.

Although there does seem to a consensus in the literature that lexical ambiguity can produce faster lexical decision times, it is not at all clear what type of ambiguity is producing the effect. Is it multiple meanings, or multiple senses that produces the advantage? One way of trying to answer this question is to examine the dictionary entries of the words used in these experiments. As described above, dictionaries make a distinction between words whose meanings are sufficiently unrelated that they are given multiple entries, and those that

have multiple senses within an entry. This provides a convenient way in which to categorise words as being ambiguous between multiple meanings or between multiple senses.

Rodd, Gaskell, and Marslen-Wilson (1999) analyzed the stimuli used in the three studies that report a significant ambiguity advantage in this way, and found that for all three studies the high-ambiguity words have more word senses than the low-ambiguity words. Further, only in the Borowsky and Masson (1996) stimuli did the two groups differ in the number of meanings. Therefore, it appears that it may be multiple senses rather than multiple meanings that are producing the ambiguity advantage. Despite this, all current explanations of the ambiguity advantage assume that the processing benefit arises because of the presence of unrelated meanings.

Models of the Ambiguity Advantage

One way that the ambiguity advantage has been explained has been to assume that ambiguous words have multiple entries within a lexical network. For example, (Kellas et al., 1988) suggest that the benefit arises because, while the multiple entries for an ambiguous word do not inhibit each other, they both act independently to inhibit all other competing entries, and this increased inhibition of competitors produces the faster recognition times.

Others have assumed that the benefit arises within this type of model by assuming that there is some level of noise or probabilistic activation (Jastrzembski, 1981). Because words with multiple meanings are assumed to have multiple entries, these words might benefit from having more than one competitor in the race for recognition; on average, by a particular point in time, one of these competitors is more likely to have reached the threshold for recognition than a word that has only one entry in the race.

Both these approaches to explaining the ambiguity advantage predict that the effect will occur whenever the different meanings of the ambiguous words are sufficiently unrelated to have separate entries in the mental lexicon; they make no specific predictions about what should happen for words with multiple senses, as it is not clear whether word senses would correspond to separate entries within the network.

An alternative view of word recognition is that words compete to activate a representation of their meaning. There have been several recent models of both spoken and visual word recognition that have taken this approach (Hinton & Shallice, 1991; Plaut & Shallice, 1993; Joordens & Besner, 1994; Gaskell & Marslen-Wilson, 1997; Plaut, 1997). These models use distributed lexical representations; each word is represented as a unique pattern of activation across a set of orthographic/phonological and semantic units.

Within models of this type, the orthographic pattern *bark* must be associated with two different semantic patterns corresponding to its two meanings. When the orthographic pattern is presented to the network, the network will try to instantiate the word's two meanings across the same set of semantic units simultaneously. These competing semantic representations will interfere with each other, and this interference is likely to increase the time it takes for a stable pattern of activation to be produced. Therefore, it appears that these models predict that lexical ambiguity should delay recognition, and not produce the faster response times seen in the literature.

In response to this inconsistency between the ambiguity advantage literature and the predictions of semantic competition models, there have been several attempts to show that, given particular assumptions, this class of model can overcome the semantic competition effect, and show an advantage for ambiguous words (e.g. Joordens and Besner (1994), Borowsky and Masson (1996) and Kawamoto, Farrar, and Kello (1994)). Importantly, these models assume that the effect to be modelled is an advantage for those words with multiple unrelated meanings.

Thus, the ambiguity advantage has been interpreted within a range of models of word recognition. However, all these accounts have implicitly assumed that the ambiguity advantage literature demonstrates that there is a processing advantage for words with more than one, unrelated, meaning. As discussed above, it is not clear that this is the case; the ambiguity advantage may be a benefit for words with multiple *senses* rather than multiple *meanings*. In order to understand fully the implications of semantic ambiguity for models of word recognition, we need to determine which of these explanations is correct.

Experiment 1: Visual Lexical Decision

Method

Experimental Design This experiment attempts to separate out the effects of lexical ambiguity and multiple word senses by using a factorial design (see Table 1). Groups of ambiguous and unambiguous words were selected to have either few or many senses on the basis of their dictionary entries.

Table 1: Experiment 1: Experimental Design

Ambiguity	Senses	Example
Ambiguous	Few	pupil
Ambiguous	Many	slip
Unambiguous	Few	cage
Unambiguous	Many	mask

Participants The participants were 25 members of the MRC Cognition and Brain Sciences Unit subject panel. All had English as their first language, and had normal or corrected-to-normal vision.

Stimuli The word stimuli were selected to conform to a 2 x 2 factorial design, where the two factors were ambiguity and number of senses. Words were classed as being unambiguous if they had only one entry in The Online Wordsmyth English Dictionary-Thesaurus (Parks, Ray, & Bland, 1998), and as ambiguous if they had two or more entries. Two measures of the number of senses were used. These were the total number of word senses listed in the Wordsmyth dictionary for all the entries for that word, and the total number of senses given in the WordNet lexical database (Fellbaum, 1998).

Thirty-two stimuli were selected to fill each cell of the factorial design, such that the number of word meanings was matched across each level of number of word senses, and the total number of word senses was matched across each level of the number of word meanings.

The four groups of words were matched for frequency in the CELEX lexical database (Baayen, Piepenbrock, &

Van Rijn, 1993), number of letters, number of syllables, concreteness and familiarity. Concreteness and familiarity scores were obtained from rating pre-tests in which all the words were rated on a 7-point scale by participants who were members of the MRC Cognition and Brain Sciences Unit subject panel, and who did not participate in the lexical decision experiment.

The groups were not explicitly matched for neighbourhood density; however, the number of words in CELEX that differed from each word by only one letter (N; Coltheart, Davelaar, Jonasson, & Besner, 1977) was calculated for each word. An analysis of variance (ANOVA) showed that the words in the four groups did not differ significantly on this measure; $F(3, 124) = 1.02, p > .3$.

The non-word distractors were pseudohomophones, such as *brane*, with a similar distribution of word lengths to the word stimuli. Pseudohomophones were used because both (Azuma & Van Orden, 1997) and (Pexman & Lupker, 1999) found stronger effects of semantic ambiguity when these non-words were used. In this first experiment, we wanted to maximise the chance of finding significant effects of ambiguity.

Procedure All the stimulus items were pseudo-randomly divided into four lists, such that each list contained approximately the same number of words from each stimulus group. Participants were presented with the four lists in a random order, with a short break between lists. Within the lists, the order in which stimulus items were presented was randomised for each participant. All participants saw all of the stimulus materials. A practice session, consisting of 64 items not used in the analysis, was given to familiarise participants with the task. Each block began with 10 stimuli not included in the analysis.

For each of the word and non-word stimuli, the participants were presented with a fixation point in the centre of a computer screen for 500 msec, followed by the stimulus item. Their task was to decide whether each item was a word or a non-word; recognition was signalled with the dominant hand, non-recognition with the other hand. As soon as the participant responded, the word was replaced with a new fixation point.

Results

The data from two participants were removed from the analysis, because of error rates greater than 10%. 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 to minimize the effect of outliers (Ulrich & Miller, 1994; Ratcliff, 1993). Incorrect responses were not included in the analysis. The overall error rate for responses was 3.6%.

Mean values were calculated separately across participants and items. The participant means were subjected to an ANOVA, and the item means were subjected to an analysis of covariance (ANCOVA) with frequency, familiarity, concreteness and length entered as covariates. The mean response times are given in Figure 1.

The ANCOVA revealed significant effects of frequency, familiarity, length and neighbourhood density (all $p < .05$). The effect of concreteness was non-significant ($p > .5$), so this variable was removed from the ANCOVA. The response
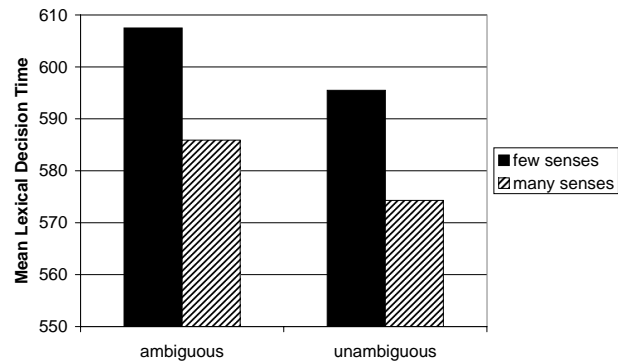

Figure 1: Experiment 1, mean lexical decision times

time data revealed a main effect of the number of senses ($F_1(1, 22) = 14.22, p < .001; F_2(1, 120) = 4.51, p < .05$). Words with many senses were responded to faster than words with few senses. The effect of ambiguity was marginal in the participants analysis ($F_1(1, 22) = 3.77, p < .07$), but non-significant in the items analysis ($F_2(1, 120) = 1.67, p > .2$). Ambiguous words were responded to more slowly than unambiguous words. There was no significant interaction between these two variables ($p > .2$).

The error data also showed a significant effect of the number of senses; fewer errors were made for words with many senses ($F_1(1, 22) = 12.2, p < .005; F_2(1, 120) = 5.19, p < .05$). In the error data neither the effect of ambiguity nor the interaction between the two variables reached significance (all $p > .4$).

Discussion

This experiment shows that words with many senses were responded to faster and with fewer errors that words with few senses. This advantage for multiple senses is in contrast with a *disadvantage* for words with multiple meanings. Although this disadvantage was not significant, it is clear that contrary to the accepted view in the literature, there is no processing advantage for words with multiple meanings. Moreover, Rodd et al. (1999) did find a significant disadvantage in visual lexical decision for words with more than one meaning, compared with unambiguous words, when the stimuli were selected to minimise the effect of word senses. Thus, previous reports of an ambiguity advantage must be the result of the multiple senses of the high-ambiguity stimuli rather than their multiple meanings.

Therefore, the results of this experiment together with the results of Rodd et al. (1999) show that the two types of lexical ambiguity have opposite effects on visual word recognition; while ambiguity between multiple meanings may delay recognition, ambiguity between multiple senses is beneficial.

The following experiment will investigate whether this pattern is also seen in the auditory domain. If the above pattern of data is telling us something interesting about the way in which word meanings are stored and processed, we should expect to find the same pattern independent of the input modality.

This experiment will also allow us to establish that these

effects of semantic ambiguity are not contingent on the type of non-word distractors used. In Experiment 1, pseudohomophones such as *brane* were used. There is still debate about how pseudohomophones affect lexical processing (see Pexman & Lupker, 1999 for a review). One possibility is that they simply increase the difficulty of the task, and so increase sensitivity to relatively small effects. However, an alternative explanation is that pseudohomophones strategically effect the way that participants make use of orthographic, phonological and semantic information. The following experiment, which does not use pseudohomophones will attempt to demonstrate that these effects are not due to strategic effects induced by these particular non-words.

Finally, this experiment will also allow us to try and replicate the significant ambiguity disadvantage seen by Rodd et al. (1999).

Experiment 2: Auditory Lexical Decision

Method

Experimental Design   The experimental design was identical to Experiment 1.

Participants   The participants were 26 students at Cambridge University who had not participated in the first experiment. All had English as their first language, and had normal or corrected-to-normal vision.

Stimuli   23 stimuli were selected to fill each cell of the factorial design, such that the number of word meanings was matched across each level of number of word senses. The words were selected on the basis of dictionary entries as in Experiment 1. The number of words in each cell is smaller than was used in Experiment 1, because of the additional constraints used to match the groups. 77% of the words were also used in Experiment 1.

The four groups of words were matched for frequency, number of phonemes, the phoneme at which the word becomes unique, actual length of the words in msec, concreteness and familiarity. Concreteness and familiarity scores were obtained from the same rating pre-test as in Experiment 1. All the words had only one syllable.

The non-word stimuli were created to be as word-like as possible, and to have a similar distribution of word lengths to the word stimuli.

Procedure   The procedure used was the same as that in Experiment 1, except that now the stimuli were spoken words. Each item appeared 1000 ms after the participants' response to the preceding item. If the participant did not respond within 3000 ms of the onset of a word, the next item was presented.

Results

The data from four participants were removed from the analysis, because of error rates greater than 10%. Incorrect responses were not included in the analysis. The overall error rate for responses was 5.8%.

As in Experiment 1, inverse response times were used in all analyses. Mean values were calculated separately across participants and items. The participant means were subjected to an analysis of variance (ANOVA), and the item means were subjected to an analysis of covariance (ANCOVA), with familiarity and length entered as covariates. The mean response times are given in Figure 2.
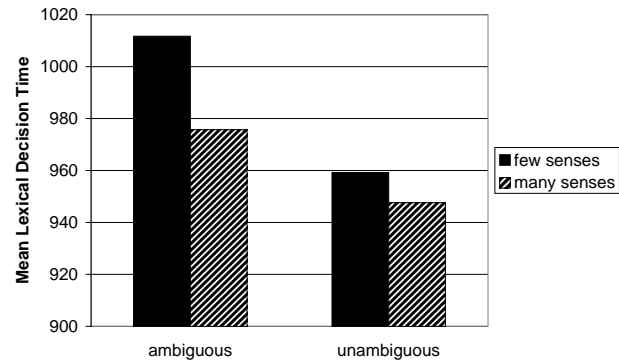

Figure 2: Experiment 2, mean lexical decision times

The ANCOVA revealed significant effects of familiarity ($r = -.26, p < 0.05$) and length ($r = -.75, p < 0.001$). Concreteness, frequency, number of phonemes and uniqueness point were not significant predictors of response times ($p > .2$), so these variable were not included in the ANCOVA.

The main effect of the number of word senses was significant in both the participants and items analysis ($F_1(1, 21) = 16.9, p < .001; F_2(1, 86) = 4.4, p < .05$). Words with many senses were responded to faster than words with few senses. The effect of ambiguity was also significant in both the participants analysis and the items analysis ($F_1(1, 21) = 27.8, p < .001; F_2(1, 86) = 7.4, p < .005$). Ambiguous words were responded to more slowly than unambiguous words. The interaction between these two variables was marginal in the subjects analysis but did not approach significance in the items analysis ($F_1(1, 21) = 3.8, p < .1; F_2(1, 86) = 0.4, p > .5$).

The error data showed a similar pattern of results to the response time data. Fewer errors were made for words with many senses, although this difference was significant only in the subjects analysis but not in the items analysis; ($F_1(1, 21) = 10.5, p < .005; F_2(1, 86) = 2.7, p = .1$). Fewer errors were also made for unambiguous words, although this difference was only marginal in the subjects analysis and did not approach significance in the items analysis; ($F_1(1, 21) = 4.2, p < .06; F_2(1, 86) = 0.7, p > .4$). The interaction between the two variables was not significant in either analysis ($p > .5$).

General Discussion

Both the experiments reported here have shown an advantage for words with many word senses. This advantage for multiple senses was seen alongside a disadvantage for words with multiple meanings. This suggests that the ambiguity advantage reported in earlier studies must have been produced by the high number of related word senses of high-ambiguity stimuli, and not by their unrelated meanings.

What are the implications of this new pattern of results for models of word recognition? Previously, these models had

been required to produce an advantage for words with multiple meanings, but our data suggests they must accommodate exactly the reverse effect. In fact, this is less problematic than might be expected.

The ambiguity disadvantage can easily be explained by models in which words compete for the activation of semantic representations (Hinton & Shallice, 1991; Plaut & Shallice, 1993; Joordens & Besner, 1994; Gaskell & Marslen-Wilson, 1997; Plaut, 1997). As discussed earlier, in these models competition between the different meanings of ambiguous words would delay their recognition. As noted by Joordens and Besner (1994), an ambiguity advantage can only be produced by these models if an additional mechanism is present to overcome this semantic competition. These results suggest that no such mechanism is required.

The other class of model that may be able to accommodate this new pattern of results is those models in which words compete to activate abstract word nodes within a lexical network. Earlier, we discussed how these models could produce an ambiguity advantage by assuming either that ambiguous words are more efficient at inhibiting competitors, or that they benefit from having multiple competitors in the race for recognition.

Surprisingly, these models can just as easily accommodate a disadvantage for words with multiple meanings. As in all experiments of this type, the ambiguous words and unambiguous words in these experiments were matched on total frequency. This means that the frequency of each meaning of the ambiguous words is on average half that of the unambiguous word. This frequency difference could produce faster lexical decisions for the unambiguous words. Similarly, if lateral inhibition were present between all word nodes, including the nodes corresponding to the different meanings of an ambiguous word, this would act to slow the recognition of ambiguous words.

Therefore, it appears that both classes of models considered here can be modified to accommodate the finding of slower responses to words with more than one unrelated meaning. However, Rodd et al. (1999) have shown that at least in the visual domain, the ambiguity disadvantage is modulated by the rated relatedness of the two meanings of the ambiguous words; words whose meanings are sufficiently different to be considered meanings rather than senses but whose meanings are mildly related are responded to more quickly that those whose meanings are highly unrelated. This suggests that semantic representations are actively involved in the process that produces the ambiguity disadvantage, and that the effect cannot be explained solely as the result of a frequency bias for unambiguous words or lateral inhibition between abstract word nodes. Therefore, the ambiguity disadvantage may more easily be explained as the result of semantic competition which is maximal when the competing representations are unrelated.

It is therefore apparently straightforward to explain the observed ambiguity disadvantage. The intriguing question that remains is what causes the advantage for words with many senses?

One possibility is to explain this effect in terms of the attractor basins that develop in a distributed semantic network. The different senses of a word correspond to a set of highly correlated patterns of semantic activation. As noted by Kawamoto (1993), for a word with many related senses, these senses will create a broad and shallow basin of attraction, containing more than one stable state corresponding to each different sense. It is plausible that within certain architectures, settling into the correct attractor may be quicker for such a broad attractor, compared with the attractor of a word with few senses, or that the multiple stable states within the attractor may lead to faster settling times. This suggestion needs to be assessed by performing the appropriate simulations.

A second possible explanation of the sense effect would be to consider the difference between words with many and few senses as reflecting a difference in the amount of semantic information associated with the two types of words. In other words, a word with many senses may be considered to be semantically rich. This is essentially the same argument that Plaut and Shallice (1993) put forward to account for the processing benefit of concrete words over abstract words. In their computational account of the concreteness effect, the difference between abstract and concrete words is reflected in the number of semantic features in a distributed semantic representation; abstract words are given fewer semantic features than concrete words. This results in concrete words activating more stable representations than abstract words. These stable representations lead in turn to faster settling times for words with more semantic features.

It is not yet possible to distinguish between these (and other) possible explanations of the sense effect reported here. A combination of network simulations and further experiments is required to determine how existing models of word recognition should be modified to accommodate the benefit for words with many word senses. What is clear is that the distinction we have emphasised between word meanings and word senses is critical. In the past, ambiguity has been treated as a unitary property of words; we have shown that this has masked an informative pattern of results that can be used to constrain models of how words are recognised.

More generally, these experiments emphasise how word recognition is inextricably linked with word meanings. Data of this kind places an increasing demand on models of word recognition to incorporate richer semantic representations that reflect the complex structures of the meanings of words.

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