A Context-Sensitive Frequency-Based Theory of Meaning Achievement

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The basic problem for the psychologist interested in any form of human communication is how meaning is achieved by the organism. The present chapter has a twofold purpose: (1) to present evidence for the role of frequency in resolving semantic ambiguity and (2) to elucidate a theory of frequency action that has generality for human information processing. We will argue that the most important role in understanding the processing of words is that the processing will depend on the frequency of the word. Robinson's classic statements (1932) of the law of frequency were recently updated by Slamecka (1987) in the following words:

Since that time, psychologists have considerably extended the list of effective variables, but the impression that I receive from my review is that these other variables tend to play their roles superimposed against a larger background, which reduces them almost to local eddies that are swept along in the irresistible tide of repetition increments (p. 128).

We believe the data with respect to the processing of homographs support a similar statement; i.e., the law of frequency will apply to the task.

In the first part of this chapter we will review five studies conducted in our laboratory that we believe consistently call for a frequency principle to interpret their results. In the second part of this chapter, we will offer an explanation of those results in the form of a theory of how and why frequency operates in language processing.

Frequency Defined

In the definition of frequency we follow the convention described under characteristics of materials in Chapter 1 (p. 10). We distinguish between polarity (the relative frequency of each of the meanings of a homograph) and frequency in print as derived from normative studies like that of Kucera and Francis (1967). We treat these two measures as independent, and design our studies to test a full range of both polarity (from balanced to unbalanced homographs) and normative frequency (from low to high). Polarity represents an intra-individual difference and is not merely a result of averaging subjects who differ with respect to the dominant association. Thus an individual who responds in word association in the secondary direction with respect to an item that is highly polarized in the group will tend to change to the alternate (primary) meaning when asked to produce subsequent associations to that word. On the other hand, if an association is in the normatively primary direction, subsequent associations tend to stay in that direction. Homographs of more balanced polarity produce changes in meaning in continuous association, as shown in the normative study of Gorfein, Viviani, and Leddo (1982). In a similar fashion, test-retest scores were more stable in the study of Geis and Winograd (1975) for highly polarized homographs.

Frequency and the Ambiguity Decision

We begin with experiments in which the participant's task is to decide whether a given letter string is a homograph (i.e., does it, the letter string, have two or more distinct meanings or fewer than two meanings?). Historically, the earlier studies employing the ambiguity task were among the very few to study a full range of word frequency and polarity in single studies (Forster & Bednall, 1976; Hogaboam & Perfetti, 1975). Recently, we (Cooper, Gorfein, & Bubka, 1988) had the occasion to employ the ambiguity task in an attempt to elucidate some apparent contradictions between the results of Hogaboam and Perfetti and those of Forster and Bednall.

Specifically, Hogaboam and Perfetti (1975) primed their ambiguity decisions with a sentence context and analyzed all the response times obtained, while Forster and Bednall (1976) presented words singly and analyzed only correct response times. The most conflicting result would appear to be the absence of a polarity effect in the Forster and Bednall study and the large effect of polarity in the study by Hogaboam and Perfetti. We believed there would be an interaction of homograph polarity and Kucera-Francis frequency in such manner that for balanced homographs the errors and reaction times would be largely independent of Kucera-Francis frequency. However, as polarity increased, secondary meanings would become more difficult to achieve, especially when the overall (Kucera-Francis) frequency of the homograph was low. We examined these effects on the same materials in two experiments. In Experiment 1, single words were presented for ambiguity decision, whereas for Experiment 2, the words were primed by a related or unrelated item. Both studies presented nonwords as well. The conditions of the two experiments are outlined in Table 7.1. The materials employed were three levels of homographs (polarity: balanced 50-65%, middle 66-85%, and unbalanced 86-100%). Within each of these levels
Table 7.1. Design of Experiments 1 and 2.

**Experiment 1.**

**Targets:** 80 homographs, 12 nonhomophonic homographs, 66 unambiguous words, and 46 pronounced nonwords

**Procedure:** Target's presented singly for ambiguity decision

**Experiment 2.**

**Targets:** Same as Experiment 1 but primed for 75S with related item or re-paired to form unrelated pairs as shown below

<table>
<thead>
<tr>
<th>Type of material</th>
<th>Related</th>
<th>Unrelated</th>
</tr>
</thead>
<tbody>
<tr>
<td>80 homographs</td>
<td>PRIMING</td>
<td>RAILROAD</td>
</tr>
<tr>
<td></td>
<td>target:</td>
<td>BANK</td>
</tr>
<tr>
<td>12 nonhomophonic</td>
<td>PRIMING</td>
<td>BANK</td>
</tr>
<tr>
<td>homographs</td>
<td>target:</td>
<td>SECONDARY</td>
</tr>
<tr>
<td>(Heterophones not</td>
<td>PRIMING</td>
<td>TEACH</td>
</tr>
<tr>
<td>included in analysis)</td>
<td>target:</td>
<td>BANK</td>
</tr>
<tr>
<td>66 unambiguous</td>
<td>PRIMING</td>
<td>COLESLAW</td>
</tr>
<tr>
<td>words</td>
<td>target:</td>
<td>PRIEST</td>
</tr>
<tr>
<td>46 pronounceable</td>
<td>PRIMING</td>
<td>COLESLAW</td>
</tr>
<tr>
<td>nonwords</td>
<td>target:</td>
<td>PRIEST</td>
</tr>
<tr>
<td>204 prime target</td>
<td>PRIMING</td>
<td>PSEUDOWORD</td>
</tr>
<tr>
<td>pairs</td>
<td>target:</td>
<td>PREEST</td>
</tr>
</tbody>
</table>

There were some instances of low Kucera-Francis frequency (less than the natural log value of 2), medium frequency (logs from 2 to 4), and high frequency (above a log of 4). There were also a number of unambiguous words of the same frequency range and a set of nonwords constructed from the unambiguous words.

Table 7.2 presents the response times and errors as a function of frequency and materials for the unprimed condition. Following the procedure of Hogaboam and Perfetti, all response times are included in the analysis in order to reflect the length of all decisions.

Our major focus is on the analysis of the error data for the homographs as a function of frequency, i.e., the polarity by frequency interaction. In particular, the homographs which are low frequency in use and which are highly unbalanced produce performance (52% correct) that does not differ reliably from chance. With respect to the main effect of polarity, the data are quite striking, with error rates increasing as homographs become increasingly unbalanced. Decision latencies follow the pattern of errors.

It is interesting, in terms of modeling the data, to look at the error rates and decision times for the unambiguous words. With respect to frequency, both response latency and errors increase as frequency increases. We can see two alternative explanations of these data. One is that the participant uses a familiarity criterion to decide whether a search for a second alternative meaning could be fruitful. A second explanation is that the participants genuinely have more difficulty making the ambiguity decision for higher-frequency entries. For the unambiguous word, the former explanation would only account for the latency data. The latter view is discussed in terms of our theory in the section Accounting for the Data, below.

In the second experiment, half of the items presented for ambiguity processing were primed with a related word. In the case of the homographs, these primes were related to either the primary or secondary meaning equally often and re-paired to form unrelated primes. For the nonwords the prime was related to the word from which it was derived or similarly re-paired. Thus, the procedure was like that of the first experiment with the addition of a prime (related or unrelated).

On the basis of our “race” model (Gorcein & Bubka, 1985), it was hypothesized that the secondary prime would improve ambiguity-decision performance at all levels of polarity, whereas a primary prime would have little influence and might even have a negative influence.

For the unambiguous word items, there was once again a trend for frequency to influence decision latency and error rates in the same manner. The mean response latency and errors (in parentheses) were 1896 (.12), 1829 (.20), and 1988 (.20) from low to high frequency, respectively. Priming had no reliable effect. Once again, nonword decisions were much faster than word decisions and had very low error rates, 1218 ms (.02).

Table 7.3 reports the data for the homographs. Consistent with the data for unprimed homographs, the data for unrelated primes show an effect of both polarity and frequency, with the highest overall error rate (0.58) occurring for the unbalanced low-frequency homographs. With respect to Experiment 1, where words were unprimed, the decision latency for unrelated primes was slightly longer, but error rates were about the same.

Priming with related primes produces some very interesting effects with respect to error rates. While secondary primes (Table 7.3c) produced significant improvement with respect to errors as compared with unrelated
Table 7.3. Decision time in milliseconds and proportion of errors (in parentheses) for the homographs presented in the primed ambiguity task.

<table>
<thead>
<tr>
<th>Homograph polarity</th>
<th>Balanced (50–65%)</th>
<th>Middle (66–85%)</th>
<th>Unbalanced (86–100%)</th>
<th>Mean (50–100%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Unrelated prime</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>1772(27)</td>
<td>1922(34)</td>
<td>2153(59)</td>
<td>1943(40)</td>
</tr>
<tr>
<td>Middle</td>
<td>2006(34)</td>
<td>1851(18)</td>
<td>2118(27)</td>
<td>1992(26)</td>
</tr>
<tr>
<td>High</td>
<td>1990(21)</td>
<td>2111(27)</td>
<td>1951(39)</td>
<td>2017(22)</td>
</tr>
<tr>
<td>Mean</td>
<td>1923(27)</td>
<td>1961(26)</td>
<td>2068(42)</td>
<td>2017(22)</td>
</tr>
<tr>
<td>b. Primary prime</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>1727(15)</td>
<td>1752(33)</td>
<td>1928(53)</td>
<td>1806(34)</td>
</tr>
<tr>
<td>Middle</td>
<td>1919(32)</td>
<td>1952(27)</td>
<td>1999(48)</td>
<td>1907(36)</td>
</tr>
<tr>
<td>High</td>
<td>1617(38)</td>
<td>1827(30)</td>
<td>1863(41)</td>
<td>1769(36)</td>
</tr>
<tr>
<td>Mean</td>
<td>1754(38)</td>
<td>1847(30)</td>
<td>1908(47)</td>
<td></td>
</tr>
<tr>
<td>c. Secondary Prime</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>1670(15)</td>
<td>1846(27)</td>
<td>1810(36)</td>
<td>1775(26)</td>
</tr>
<tr>
<td>Middle</td>
<td>1906(20)</td>
<td>1822(17)</td>
<td>1900(30)</td>
<td>1896(22)</td>
</tr>
<tr>
<td>High</td>
<td>1699(17)</td>
<td>1789(24)</td>
<td>1880(24)</td>
<td>1789(22)</td>
</tr>
<tr>
<td>Mean</td>
<td>1758(17)</td>
<td>1819(23)</td>
<td>1883(30)</td>
<td></td>
</tr>
</tbody>
</table>

The primary prime had negligible effects and indeed seemed to increase errors. Both primary and secondary primes seem to enhance decision speed.

Thus, the principal findings with respect to the ambiguity decision are those of the interaction of frequency and polarity. The lower the frequency of the secondary meaning, as estimated by the product of the Kucera-Francis frequency of the letter string (homograph) and the normative proportion of secondary word associations, the more difficult the ambiguity decision. A search model of ambiguity decision like that of Forster and Bednall (1976) (see also Forster, Chapter 9, this volume) would predict the findings with respect to decision time. A search model with a deadline to stop searching could predict the error rates. However, the high rate of failed searches (incorrect rejections) is troubling in our view for any model that proposes a search mechanism.

The Meaning(s) Achieved

The crucial problem for the student of language processes is understanding what meaning is achieved by language processes. As mentioned in Chapter 1 of this volume, the problem is by no means a simple one. The tasks in which we study meaning are not themselves transparent, and the performance does not necessarily indicate which meaning is finally arrived at. In the literature, we are told that the meaning present may vary as a function of the posthomograph interval with both meanings of a bipolar homograph present at or shortly (200–400 ms) after the homograph, and ultimately only the primary meaning in the unprimed task and the contextually appropriate meaning in the primed persist after a longer interval (cf., Onifer & Swinney, 1981; Simpson & Burgess, 1985; Simpson, Chapter 2, this volume).

In order to evaluate meaning achieved after a variety of tasks, Bubka (1988) developed the relatedness experiment. In experiments of this type, shortly after the completion of the processing of a homograph, e.g., DUCK (i.e., the required response to that item is made), a word is presented, e.g., SWAN, with the instruction that the participants must decide if that word is related to the homograph that had just been processed. The probe words are related to one or the other meaning of the homograph (primary or secondary) or are unrelated. The simplicity of the idea is that to the degree that the homograph has already achieved a meaning state appropriate to the probe, the decision should be faster and more accurate. Further, the identical probe may follow the homograph in a variety of contexts. Thus, any differences obtained across contexts can be attributed to the task constraint and not to the homograph-target relationship alone or to the nature of the relatedness task. The studies reported in Bubka’s dissertation and in a follow-up study we conducted all ask what manipulations favor one meaning state or the other.

In the third experiment we report here, we were interested in the meaning achieved in lexical decision. The priming effects observed in lexical decision are considered an indication of lexical access, although the exact processes by which access occurs, and what meaning is achieved, are debatable. Since the ambiguity-decision task is transparent to the meanings achieved, the two tasks (lexical decision and ambiguity decision) were compared in terms of performance as measured on a relatedness decision that followed the orienting task on a homograph.

When presented with a word in an ambiguity-detection task, the participant decides whether the word has one meaning or more than one meaning. The homographs used in this study have only two meanings; therefore, presumably both meanings will have been achieved when an ambiguous word is presented and a correct response is produced.

In the lexical-decision task, the participant decides if a string of letters is a word or a nonword. Retrieval of one meaning is logically sufficient to make a lexical-decision judgment. If the string of letters has some meaning and a lexical entry has been found, then it must be a word. Lexical access may or may not be exhaustive. Table 7.4 gives an outline of this task.

The orienting task (ambiguity decision, lexical decision), a between-subjects variable, preceded the relatedness-decision task. In the relatedness task, the participant decided if a word was related in meaning to the
Table 7.4. Lexical, ambiguity, and relatedness decision in Experiment 3.

<table>
<thead>
<tr>
<th>Relatedness decision</th>
<th>Orientation task</th>
<th>Lexical decision</th>
<th>Ambiguity task</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Homograph</td>
<td>Nonword</td>
</tr>
<tr>
<td>a. Primary meaning</td>
<td>BANK</td>
<td>FANK</td>
<td>CAT</td>
</tr>
<tr>
<td>b. Secondary meaning</td>
<td>MONEY</td>
<td>XXX</td>
<td>STREAM</td>
</tr>
<tr>
<td></td>
<td>BANK</td>
<td>FANK</td>
<td>CAT</td>
</tr>
<tr>
<td></td>
<td>STREAM</td>
<td>XXX</td>
<td>STREAM</td>
</tr>
</tbody>
</table>

Homograph presented for lexical or ambiguity decision. Response latencies and error rates of the relatedness decision should depend on the meaning(s) accessed for the homograph as a result of the orienting task. If the results are similar on the relatedness decision across orienting tasks, then it is reasonable to conclude that an exhaustive process occurs during lexical decision since it must occur for ambiguity decision. On the other hand, if differences result, this would support the idea of some form of process that achieves only a single meaning.

The main variable of interest is the effect of target type on the relatedness decision after each orienting task. If an exhaustive-access process is not occurring during lexical decision, then there should be a larger difference between primary and secondary relatedness decisions after the lexical decision than after the ambiguity decision. This difference would be found in response latency and error rate data. If only one meaning is achieved during lexical decision, then more errors and longer latencies should be found for the unaccessed meaning.

It is reasonable if differences are observed, they will be determined by the polarity of the homograph. The most frequent meaning of the homograph should be the meaning that is achieved post-lexical decision. Response latencies and errors should increase for secondary-meaning targets for relatedness decisions as polarity increases. In the same manner, they should decrease as polarity increases when a primary-meaning target is presented for relatedness decision.

The results were analyzed in terms of the difference between primary and secondary targets in the relatedness experiment. The results indicate that the outcome of the decision process under the two tasks are entirely different. As shown in Table 7.5, there were larger differences between the primary- and secondary-meaning targets for relatedness decision after the lexical decision than after the ambiguity decision, and these differences grew with polarity. Latency data showed greater differences in the lexical decision as well, but this effect was not statistically reliable.

Since we only analyzed correct reaction times, the failure to obtain a reliable orienting task by target by polarity interaction may have been due to the significant interaction observed in the error rates creating an item selection effect. The signal detection analysis indicated that there was more sensitivity toward the secondary-meaning target after the ambiguity decision than after the lexical decision. The difference scores, together with a decreasing response latency and error rate as polarity increased in lexical decision, indicate that in an unprimed lexical decision, only one meaning is achieved, usually the primary meaning.

In Experiment 3, we established that in contrast to the ambiguity-decision task the result in unprimed lexical decision is not exhaustive; rather, often the most frequent meaning is achieved. A second experiment employing the relatedness-decision task (Experiment 4) was designed to examine the effect a prime has on the meaning achieved in lexical decision. It has been hypothesized by most of the lexical-access theorists that context influences the achievement of meaning. Since we found in Experiment 3 that the polarity of the homograph had a large effect, Experiment 4 examined the effect that context had on the process. Does context determine the meaning, or is polarity more important to the process, or do the two variables interact in some way?

As shown in Table 7.6 the participant’s task in Experiment 4 was to perform a lexical decision on a homograph (or a nonword) after viewing a prime, which was a word related to one of the meanings of the homograph. After the lexical-decision task, the subject made a relatedness decision between a primary- or secondary-meaning target word and the homograph which was presented for lexical decision. The meaning of the prime and the target word for relatedness decision was always consistent. That is, it was
never the case that a primary-meaning prime preceded the lexical decision and a secondary-meaning target was presented for the relatedness decision. The inclusion of this type of trial would have left open the possibility of a strategy in which participants would consciously access both meanings of the homograph. The design, however, does favor any model that depends on the context for meaning selection. That is, to the extent that meaning achievement is context-sensitive, the meaning presented as a prime should be the meaning that is available post-lexical decision and post-access.

To the extent that meaning achievement is not context-sensitive or context-independent, the role of polarity should influence performance as it did in the unprimed lexical-decision portion of Experiment 1. Therefore, under a context-determined process, no differences between primary and secondary targets for relatedness decision or for balanced and unbalanced homograph conditions are predicted. If polarity affects lexical access, such that the primary meaning is accessed even under secondary-meaning context conditions, then differences should result between target types. Greater differences should result under unbalanced homograph conditions than balanced homograph conditions, since, for the latter materials, primary and secondary are somewhat arbitrary.

The results indicate that priming was influential in the task. Relatedness decisions were faster when the prime was related than when it was unrelated. Context is an important variable in lexical access, since it facilitates the process. However, the results shown in Figure 7.1 do not indicate that context solely determines access, since they are for correct decisions only. An analysis of errors is necessary to round out the picture.

Fewer errors (rejections) were produced for primary targets than for secondary targets on the relatedness-decision task. Also, fewer errors resulted for balanced homographs than for unbalanced homographs. As can be seen in Figure 7.2a, error rates for the secondary targets increased across polarity, while the rates for the primary targets did not differ across polarity.

Two types of errors can occur in a relatedness experiment. An error can result from a false alarm, i.e., saying “yes” when the pair is, in fact, unrelated, and from an incorrect rejection, i.e., saying “no” to a related pair. Therefore, in order to separate errors due to participants adopting a bias toward certain conditions, a signal detection analysis was performed.
and is shown in Figure 7.2b. The signal detection analysis suggested that
the primary and secondary prime produced equal sensitivity toward the
target for the balanced homograph condition. However, for the unbal-
ced homograph condition, the primary-meaning target sensitivity in-
creased with polarity, while for the secondary meaning, there was a de-
crease in sensitivity for those targets.

We can conclude that participants were slower and erred most often
when the items were unbalanced and where the relatedness decision was
directed toward the secondary meaning. This suggests that the primary
meaning was more often available at the time of the relatedness decision.
Priming was effective in that response latencies were shorter and fewer
errors were produced for those items that were primed. Priming in the
secondary direction was more facilitative than in the primary direction,
although priming was not so effective as to equalize performance on
primary- and secondary-relatedness decisions.

In summary, the two relatedness experiments (Experiments 3 and 4)
have shown that the lexical access of homographs is determined by the
context, polarity level, and particular task involved. Context aids meaning
achievement, but context does not overshadow the polarity of the
homograph.

Since context facilitated the selection of a particular meaning but did not
determine it entirely, Experiment 5, a third relatedness experiment, was
conducted in an attempt to increase the influence of the prime in meaning
achievement. An experiment almost identical to Experiment 4 was ar-
ranged. The only change from the previous study was that following Besner
and McCann’s procedure (1988), the lexical-decision target was distorted
in that the letter string was written in alternating case (e.g., wOrD), always
beginning with a lowercase letter. Distorted targets for lexical decision
should be responded to slower than undistorted targets in lexical decision.
Besner and other investigators postulate that pattern distortion slows the
rate of processing in a letter identification process which precedes or is part
of the lexical-decision process. Since distorting the lexical-decision target
makes it harder to access meaning, we hypothesized that lexical access in
this task should utilize the context more than in an undistorted situation.

Figure 7.3 shows the effect on the lexical decision under normal (7.3a)
and distorted presentation (7.3b). The distorted lexical decision results in
longer latencies with a more pronounced priming effect than the undis-
torted lexical decisions we obtained in Experiment 4.

Figure 7.4 shows the results in terms of errors and signal detectability on
the relatedness decision in this study. More important is the comparison of
this study to Experiment 4, and this comparison can be seen by comparing
the error rates (Fig. 7.4a) and sensitivity (Fig. 7.4b) with the correspon-
ding panels in Figure 7.2. The distortion manipulation has raised d' slightly,
with the greatest advantage occurring for the balanced homograph
condition.
Figure 7.3. A comparison of lexical decision latency for undistorted homographs from experiment 3 (Figure 7.3a) to distorted homographs (Figure 7.3b) as a function of priming (primary and secondary related or unrelated) and polarity of homograph.

Figure 7.4. Performance on the relatedness decision in the distortion experiment with respect to errors as defined by incorrect rejections of related targets (Figure 7.4a) and $d'$, sensitivity in a signal detection analysis (Figure 7.4b) as a function of priming (related versus unrelated), target (primary versus secondary) and polarity of homograph.
In comparing Figures 7.1 and 7.5, we see that the response latencies present a similar picture with faster responding all around occurring with the distortion manipulation and with the greatest priming advantage accruing for the balanced and middle homograph conditions.

In summary, distorting the homographs for lexical decision produces a slightly greater influence of context, but the frequency variable is still the major determiner of meaning when the polarity of the homograph is unbalanced.

**Figure 7.5.** Decision times for the relatedness decisions in the distortion experiment as a function of priming (related versus unrelated), target (primary versus secondary) and polarity of homograph.

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7. A Context-Sensitive Frequency-Based Theory of Meaning Achievement

The Effects of Frequency and the Need for an Alternative Theory

Over the five experiments we have reported, we have seen that it often seems to be difficult to achieve the secondary meaning of a homograph. Thus in Experiments 1 and 2 we demonstrated that when Kucera-Francis frequency was low and the homograph was unbalanced (secondary frequency is low), participants have great difficulty in ambiguity decision. In the subsequent experiments the results of a relatedness-decision task were best interpreted as a failure to achieve secondary meanings especially in the lexical-decision task when the meaning measured was secondary and the homograph highly polarized. Thus as we suggested in the introduction to this chapter, there is a need to pay more attention to frequency and polarity in our theorizing.

In reviewing the current state of the field in Chapter 1, we suggested that there were five alternative classes of models extant in the field (see Chapter 1, Table 1.1). A converging theme at the Semantic Ambiguity Conference was that none of the existing models accounted for all of the data. In particular, the presence and absence of semantic context effects seemed to follow no well-understood rule. We reported the failure of subjects to have available the appropriate meaning for the relatedness task even when the context supported that meaning. Tabossi (Chapter 3, this volume) reported powerful context effects that seemed to rule out exhaustive access. Forster concluded (Chapter 9, this volume) that context can influence order of retrieval of meanings, and Simpson and Kellas (Chapter 4, this volume) suggested that once one meaning was achieved, the other was harder to obtain.

At the time of the conference, we favored a search model that placed high-frequency meanings at an advantage, as they would, on the average, occur earlier in a frequency-ordered search (Gorfein & Bubka, 1985). Nevertheless, we believed (unlike the ordered-access theorists) that context might make an entry more accessible in the search, as an appropriate prime might shorten the search for the less frequent entry. However, we could not articulate a mechanism for this shortened search. In the present chapter we abandon many of our previous assumptions and offer a model that solves the problem.

A Theory of Meaning Achievement

In 1981 I proposed a mechanism for spreading activation and the interaction of environmental and semantic context (Gorfein, 1987; Gorfein & Viviani, 1981). That view was applied primarily to episodic memory tasks, with a specific attempt to explain performance in the Brown-Peterson
short-term memory task (see Gorfein, 1987). Here we will attempt to extend the theory to the achievement (selection) of meaning in semantic memory contexts.

Listed below are the seven basic principles of the theory (as described in Gorfein, 1987):

1. Words are represented by an ordered set of attributes.
2. The processing of a word activates a number ($N$) of attributes; the number is limited by (a) task constraints—the number necessary to meet the requirements of the task—and (b) the time available, if it is less than the time needed to meet the task demand.
3. In isolation, the first $N$ attributes of a word are activated.
4. The *set principle*: Processing a word in the context of active attributes will result in the use of those attributes to the extent that the word possesses attributes in common with those that are active.
5. Attributes are activated an amount ($S$) that is determined by the time available and the task’s requirements. Use of a matching attribute results in an increment in activation, while a nonmatch decrements the activity of an active attribute.
6. Activation of an attribute is accompanied by the permanent marking of the attribute with a sampled number of elements of the current environmental context from a universe of potential contextual elements. Context is used in a manner equivalent to the “stimulus sample” in stimulus sampling theory as proposed by Estes (1950).
7. Activation decays over time as a function of initial strength. The probability that an attribute remains active over a period of $K$ seconds is an exponentially decreasing function of the length of the period and an increasing function of initial strength. Therefore, the probability that an attribute active at time $T$ is still active $K$ seconds later can be defined mathematically as equal to $e^{-kS}$.

In reviewing that model and extending it to semantic memory, we are impressed that the nature of the task could influence the stimulus sampling model. In episodic memory—short-term memory (STM)—it makes sense that the principal retrieval information should be environmental-contextual. After all, that is the nature of episode (cf. Tulving, 1983). To paraphrase the instructions for a Brown-Peterson task, the participant is instructed to judge (recognition form) or recall the last item presented for memory. Therefore, a search for environmental context information (information similar to “now”) is reasonable. On the other hand, in the semantic memory tasks, the principal search set should be composed of semantic stimuli, as they are most likely to supply answers to the question “Is it a word?” or “Does this letter string have more than one meaning?”

If we examine the information available for retrieval in an unprimed lexical or ambiguity decision, we see that the principal stimulus available is the letter string provided for decision. Under this circumstance, the retrieval could consist of entries in the system associated with this stimulus sample. Modularity (see Chapter 15, this volume) may be preserved under this system by redefining the lexicon as we have described below. Conversely, the retrieval can be from the semantic memory system. In the case of the primed-decision task, the stimulus sample would contain the letter-string stimulus and the active attributes of the prime as well as environmental elements. This suggests the following revision in the theory:

**Principle 4 (Revised). The set principle**: The stimulus sample employed in retrieval will include the active attributes at the time of retrieval in addition to the environmental contextual elements.

In this revised view, the retrieval cue, a stimulus sample, will contact memory entries most like those in the sample. Therefore, the compound retrieval cue will act like the set principle did in our previous theorizing and select meaning entries for a word presented, which will tend to support the active attributes.

The role of the sample would be to cue relevant entries in the memory system for the task at hand. Following the recent suggestion of Anderson (1987) that such a memory system might be constructed in a rational manner, we would expect that such a system would try to maximize the likelihood of achieving a correct answer while minimizing the number of false entries searched. This adds an eighth and final principle:

**Principle 8.** The retrieval system in semantic memory will generate a search (candidate) set of entries from the lexicon that meets a criterion of potential utility for the task demands.

In retrieving entries for a candidate set, then, a strength rule will be followed where the probability of an entries retrieval will be a function of the similarity of an entry’s contextual markers to that of the current stimulus sample. Entries will come into the candidate set at a rate (speed) commensurate with their contextual strength. In computer jargon, memory is content-addressable.

By setting a criterion for utility we would expect such a system to be sensitive to task demands. Thus, a speeded task might lead to a more narrow retrieval plan, while a high penalty for incorrect answers might lead to a broader and slower search due to a widened definition of the set of relevant cued objects.

**The Nature of the Lexicon**

From our new viewpoint, we feel we have detected the fallacy in our previous thought (and the thinking of a number of others) with respect to the content of the lexicon. We feel that we have fallen into the same trap that led Collins and Quillian (1969) to localize property information at the highest (most general) node to which it applied in their semantic network.
We, as they, have assumed cognitive (storage) economy. In retrospect we now think that the lexicon contains multiple entries for a word not unlike the dictionary entries for most words. Even the modest college dictionary the author uses contains in excess of 25 entries for the word hand. Such a multiple-entry proposal is not as extreme, in terms of the number of entries created, as the random-walk model of Landauer (1975) or the replication memory model of Bernbach (1970). Since entries will be cued by the environmental stimuli (i.e., memory is, in general, content-addressable), the additional entries make life more difficult than does an unabridged dictionary make word retrieval more difficult than a pocket dictionary. In fact, it may be argued that the precision gained may make the system too perfect and unable to account for failures of retrieval.

It should be noted, for those devoted to the modularity hypothesis, that in order to preserve modularity we can locate the multiple entries in the lexicon. Nothing in principle changes if we were to suggest that a word has multiple nodes in a semantic network. Thus we are proposing a multiple-entry memory with a retrieval cue which selects more than one entry for examination based on the similarity of that cue to memory entries. We will now show that such a system accounts for the data we report and the other data of interest to students of lexical ambiguity.

ACCOUNTING FOR THE DATA

In the context of a particular task, the letter string (homograph) provides the principal cue for retrieval in the absence of priming. Background (environmental) stimuli provide secondary retrieval values, which in the absence of previous experience with those contextual elements (i.e., on the first occurrence of that letter string in that context) will not influence the performance. This follows from an analysis of the retrieval problem as being not unlike the retrieval problem in Pavlovian conditioning, extending Rescorla and Wagner’s (1972) analysis to this situation. We would expect that the cue’s validity will depend on past experience (i.e., how often under those conditions the cue has predicted a particular meaning). In general, the background stimuli in the absence of the letter string will have an asymptotic value near zero (see Rescorla & Wagner, 1972, pp. 86–93).

In the presence of the letter string, the background as part of a compound will be associated with the most frequently useful meanings. Thus, we would anticipate that for each of the \( n \) entries associated with a letter string, the string and its compound would have a value associated with it predicting the utility of the entry. These values would be consistent with the past experience of the organism, and thus the more frequent entries will have higher values. Both the absolute and relative frequency of the experience of each entry may influence this outcome. Since the letter string is present for all cases, its strength will be more or less asymptotic. However, the background stimuli in a context will fluctuate from environment to environment and indeed from moment to moment under Este’s stimulus sampling rules and thus will have a smaller number of associations with each entry. Thus, the compound of a homograph string in a particular background may not always reflect the same entry as the homographic elements of the array. Therefore, the probability of retrieving any particular entry as the first will vary from the normative frequency of that entry, but, in general, reflect that order.

In the lexical-decision task the retrieval system will present, for inspection to consciousness, entries reflecting this order. Since any of these entries is lexical, the first one inspected will meet the task demands. This meaning will be the one “brought to consciousness,” and thus conscious experience will tend to reflect the relative frequencies of the meanings.

In ambiguity decision the system will presumably inspect more entries. As mentioned above, entries with a low absolute frequency will have a utility value associated with them which may be quite small. Under speed instructions, the retrieval criterion (number of entries selected for the candidate set) may be limited in such manner as not to include the low-frequency occurrences. We would anticipate this occurring when the frequency of experience with the letter string (homograph) was low and the relative experience with the two distinct meanings was very unbalanced. Such a mechanism accounts for the error distribution in our unprimed ambiguity experiment.

In general, higher-frequency homographs will have a larger search set associated with them, since more senses of the word will have been experienced in sufficient numbers to meet a criterion for inclusion in the inspection set. To the degree that the homograph is polarized with respect to its distinct meaning, we would expect longer searches since the system will inspect more items on the average before finding either an entry that meets the criterion of a second distinct meaning or the bottom of its list. If there is an upper limit on entries in the candidate set, it is possible that a second distinct meaning will not be included in the set, resulting in an error. For unambiguous words, the number of entries generated will, on the average, be greater for more frequent words, and as a consequence, searches of these sets will be longer on the average than for less frequent words.

In context, according to the revised set principle, the entries will be generated by three factors in the stimulus sample: the letter string, the active attributes, and the background stimuli–letter-string compound. This will alter the distribution (order) of the entries in the candidate set and in many cases alter the composition of the set.

The data from the primed lexical-decision-relatedness experiments (undistorted and distorted) suggest that there are limits placed on the efficacy of the prime in lexical decision at least when it is a single word. This conclusion follows from the contrast of the priming-relatedness effect in undistorted and distorted lexical decision. One possible explanation of this
is that in lexical-decision experiments the familiarity of the string is directly available and dominates (as suggested by Balota and Chumbley, 1984, but see Forster's Chapter 9 in this volume). Alternatively, it may be that in many cases the letter-string member of the stimulus set is so strongly connected to the entries associated with primary responses that the prime information is insufficient to place a primed entry at the top of the hierarchy of potentially useful responses. Thus, distortion either can make it difficult to assess familiarity or can slow the word integration process down enough to have the prime-partial information compound help form the word, and thus increase the likelihood of a primed entry being first in the order. However, in any event, the gain is small. Further research on the nature of the prime, and perhaps an increased amount of distortion, would help us understand the circumstances in which the secondary meaning is achieved.

In ambiguity processing where meaning is sought by the subject, we would anticipate the prime having a greater influence. Thus, the secondary prime would greatly increase the possibility of including in the candidate set those entries associated with the secondary meaning in the set generated. To the extent that the homograph was a highly polarized one, a secondary prime would not significantly reduce the likelihood of including in the candidate set those entries associated with the primary meaning of the homograph. On the other hand, a primary prime for highly polarized homographs may increase the error rate, as the prime may assure that all entries in the criterion set are related to the primary sense. In fact in the signal detection analysis of the primed ambiguity experiment, we saw a tendency to less sensitivity when the homograph was primed by a word related to its primary sense.

The facilitation of the related decision by an appropriate prime in Experiments 4 and 5 is notable but consistent with the theory proposed. The task is post-access for the homograph and occurs at a time interval when theories of the spreading activation type (cf. Collins & loftus, 1975) suggest activation should have decayed. However, we have argued elsewhere (Gorfein, 1987; Gorfein & Viviani, 1980) that the duration of activation is task-dependent (see theory principle 5 above). In the relatedness task it is to the participant's advantage to keep the selected entry active long enough to make the relatedness decision easier. To the extent that facilitation was obtained by priming, and it was, this view of activation duration was supported.

In addition to explaining our own findings, we need to explain the principal finding that supports the major alternative model—that of exhaustive access. As indicated in Chapter 1, the cross-modal priming task (Onifer & Swinney, 1981; Swinney & Prather, this volume, Chapter 12) produces what seems to be priming of both meanings of a homograph immediately following presentation of that homograph in sentence context. Two alternative possibilities are suggested by this model to account for those data. One is the possibility that the context is not strong enough to guarantee that the first instance in the candidate set is appropriate to the sentence. This would result in a probabilistic distribution of instances, and therefore, would lead to what looks like exhaustive access by the averaging of some solely primary and some solely secondary instances. This view argues that with sufficiently strong priming, only one meaning (the content-appropriate meaning) will be accessed. Tabossi's (1988a) data (see also Chapter 3 in this volume) are generally supportive of this view. Alternatively, there may be sufficient activation produced by having a related entry or entries anywhere in the candidate set to produce priming for brief intervals following the homograph even though only one meaning is selected. Under this view, Tabossi's results would occur whenever the prime was strong enough to ensure that no (few?) entries in the candidate set are related to the unprimed meaning. We tend to favor the former proposal but have not yet achieved unambiguous evidence to support this view.

A number of converging trends (Gorfein & Walters, Chapter 5 this volume; Simpson & Kellas, Chapter 4 this volume; Walters, 1988) have suggested that the first occurrence of an ambiguous word in a situation may result in the inhibition of performance with respect to a subsequent presentation, when that presentation is intended to evoke the alternative meaning.

According to the present theory, a stimulus complex of the ambiguous word and a sample of the environmental background is formed. This ambiguity-background complex will become attached to the entry selected on that trial. When an item recurs in the same background environment it therefore will tend to evoke the same entry. To the degree that the same entry is appropriate to the task demands performance will be facilitated. When in the case of the Simpson and Kellas manipulation that entry is inappropriate performance will be inhibited. Since the same entry is initially accessed on second occurrences, the stimulus-background association will be strengthened even though another entry is ultimately selected. Thus on the third occurrence of the ambiguity there is a tendency to favor the reselection of the entry selected on first occurrence.

The Ratcliff-McKoon Model

As we were preparing the final draft of this model, Ratcliff and McKoon's (1988) retrieval theory of priming appeared in print. The authors stopped to examine in what way our model differed from theirs. In fact the differences may be small, and we welcome the concurrent support. The differences while small are not negligible. While the Ratcliff-McKoon model does not specify which aspects of a prime are formed into a compound, our model suggests that only those attributes (elements) still active at target presentation will serve to promote retrieval. We have presented evidence
for this view in short-term memory studies of homographs (Gorfein, 1983; Gorfein & Viviani, 1981). Further research in our laboratory is being conducted to extend those findings to priming tasks. Our model makes the nature of the lexicon important, while the Ratcliff-McKoon model does allow for existing associations in memory to influence performance. Finally, in our focus of interest, homography, we attribute important effects to frequency of experience when considered in conjunction with background environmental stimuli as well as the semantic stimuli which are the focus of the Ratcliff-McKoon model.

Summary

Elsewhere in this volume (Simpson & Kellas, Chapter 4) a number of relevant arguments for a feature-constraining view of context have been cited. Other individuals, as cited by Simpson, have offered miniature theories of word retrieval. Our theory may, on the surface, appear similar to the views of those others and, indeed, that of Simpson and Kellas. However, we believe that the conditioning-retrieval route we adopt provides a mechanism that is quite different from the formal model (the logogen model of Morton, 1964) from which theories like that of Simpson and Kellas derive. Specifically, our theory does not require different resting states of a logogen system but instead makes the strength-of-context-to-response connection the determiner of probability of retrieval as well as speed of retrieval of a lexical entry.

Thus, we have a model consistent with a well-established body of literature in the functionalist tradition, i.e., most, if not all, of the memory literature from Ebbinghaus to the cognitive revolution. The present model is distinguished from the exhaustive-access models in being sensitive to semantic context and strongly influenced by prior experience, in terms of meaning frequency. We believe it can account for the data in the field, and does so by postulating a mechanism that is adaptive as well as consistent with other processes. Finally, by making use of an extended lexicon, it maintains modularity (see the discussion in Chapter 15) without sacrificing context sensitivity.

Part III  Representation

Homographs are an interesting problem to those interested in how items are represented in knowledge. The representation of a homograph is, of course, only a special case of the issue of how our words connect to our experiences. This section contains two data-driven papers addressed to resolving this issue. In Chapter 8, Marilyn Smith leaves the lexical ambiguity literature to confront representation from the point of view of the bilingual and offers tools to sharpen our analytical skills. In Chapter 9, K. I. Forster seeks to handle the paradoxes of search models with respect to the role of frequency and its implications for representation.

In addition to these authors who tend to be close to their data, Part III includes a magna theory of representation proposed by Barsalou and Billman, in Chapter 10. Starting from a view of concept stability and instability, they seek to relate experience to the types of storage, from frames to scripts, achieved. Thus they offer a framework for viewing a person's complete knowledge system.

Finally, in Chapter 11 of this section, Robert Hoffman addresses the meta theory of representation and seeks to bring to the consciousness of researchers of ambiguity the assumptions they make.