LEXICAL ACCESS DURING SENTENCE COMPREHENSION:

FREQUENCY AND CONTEXT EFFECTS

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Introduction

Lexical access is a multi-component process that involves both the access of a word's orthographic and phonological codes as well as the activation of meaning. The study of this process as it occurs during sentence comprehension is valuable for two reasons. First, we need to know how this important part of sentence processing functions in interaction with other levels of analysis. More generally, its study can provide evidence about how top-down or knowledge-level processing influences processes that occur at lower or stimulus-driven levels. In particular, in this paper I report on a series of experiments concerned primarily with how semantic information as well as information about frequency of use of word meanings affects that part of the lexical process that involves the activation of meaning. For ease of presentation I use the term "lexical access" throughout this paper to refer only to that part of the process.

We know from previous research on lexical access that it is both an autonomous and automatic process. Let us consider the autonomous aspect first.

There are many levels of analysis in sentence processing - the phonological/orthographic, lexical, syntactic, semantic, and pragmatic levels are the ones commonly recognized. These levels must be discrete to be considered as separate modes of analysis but must also interact if a coherent representation of a sentence is to be achieved. How does this exchange of information between levels occur? There are two predominant views on the matter. According to the autonomous model (Garrett, 1978; Forster, 1979; and Swinney, 1979), processing within a level (or "module") is carried on in isolation from processing at other levels. Interaction is limited to the outputs of processing. In the alternative model (Marslen-Wilson and Tyler, 1980) information from higher levels of analysis can facilitate the processing that occurs at lower levels before that processing has been completed.

Evidence for the autonomy of lexical access comes from the study of lexical ambiguity resolution. Many words are associated with more than one meaning. For example, "draft" can mean either "conscription" or "breeze". In a sentence where biasing context precedes the ambiguous word both semantic and syntactic information is available for aiding disambiguation. The crucial question for the autonomy issue is whether this higher-level information acts to restrict access to only the appropriate sense (prior decision hypthesis) or whether it can only have an effect on the process after both meanings are accessed (post decision hypothesis). The former hypothesis is consistent with the interactive model the latter with the autonomous model.

The work of Swinney (1979) and Tanenhaus, Leiman, and Seidenberg (1979) using cross-modal priming has shown that the post-decision hypthesis is correct. Cross-modal priming is a technique based on the priming paradigm developed by Meyer and Schvaneveldt (1971). They found that the time to decide if a visually presented string of letters is a word (the lexical decision task) is facilitated if a semantically or associatively related word is presented just prior to the target. This result supports a model of semantic memory wherein word meanings are contained in a network of nodes that pass activation along connecting arcs to other, semantically related nodes (Collins & Loftus, 1975). In cross-modal priming the word priming the visual target is presented auditorily. In this way, the priming effect is maintained and lexical access can be studied "on-line", that is, during the actual processing of the sentence. In Swinney (1979), subjects listened to sentences containing ambiguous words in which the sentences were biased towards one or the other meanings of that word. Simultaneous with the offset of the auditorily presented ambiguous word, subjects saw a visual target that was related to one or the other meaning of the word, or a control, as in the following example:

Auditory Stimulus: The man was not surprised when he found spiders,
roaches, and other bugs in the corner of his room.
↑

Visual target: ant
spy
sew

Subjects had to decide if the visual target was a word. Swinney found that targets related to either meaning of the ambiguous word were responded to more quickly than the control target, indicating that both meanings had been activated. Since this occurred even though his sentences were strongly biasing, he concluded that the post-decision hypothesis was correct.

Swinney used noun-noun ambiguities in his study, demonstrating that semantic and pragmatic information could not influence the lexical access process until its outputs were available (4 syllables later only the appropriate meaning was still activated). Tanenhaus, Leiman, and Seidenberg (1979), showed that this was true for syntactic information as well by embedding noun-verb ambiguities (e.g., "rose") in syntactically disambiguating contexts. They used a naming latency task to measure activation. In naming latency, the time to initiate the pronunciation of a visually presented word is measured. They found that visual targets related to either meaning of an ambiguous word were primed even in syntactically disambiguating contents, again confirming the post decision hypothesis.

Another aspect of the model of lexical access is that it is an automatic process. A number of psychologists have made a distinction between automatic and attentional processes (Kahneman, 1973 and Schiffrin and Schneider, 1977), where attentional processes are controlled, use a pool of limited capacity and are characterized by inhibition of responses that compete with the task at hand. Automatic processes are not under conscious control, do not use capacity, and exhibit facilitation of certain responses but no inhibition. Lexical access appears to be an automatic process since the access of meanings is not under control. Both meanings are always accessed regardless of biasing context. Also, while there was facilitation of responses related to the word in the studies cited above, there was no inhibition of unrelated responses.

Further Determination of the Model

Our knowledge of lexical access is by no means complete. The aspects of the process I undertook to investigate were frequency effects and time course. Previous studies had looked only at the 0 msec. delay and at one delay after word offset. Given how quickly access and decision processes were found to take place, I thought it was necessary to probe at a number of delays to get a more complete picture of the process. In particular, I was interested in the effect of context at different delays. Was it true that context provided no input to the access process until access had been completed? Or was it that its effects were not discernable at the 0 delay? Perhaps probing at the beginning of the word, just at the start of lexical access, might be more revealing of the influence of context than probing at the end of the word when the process was already well under way.

Another issue that concerned me was frequency effects. The meanings of an ambiguous word differ in the frequency with which they occur in language use. For example, the "harbor" interpretation of "port" is more often encountered than the "wine" meaning. Hogaboam & Perfetti (1975) suggested that information about frequency is contained in the lexical netwok in such a way that dominant meanings are always accessed first and compared with context for appropriateness. Subordinate meanings are only accessed if the dominant meaning is not intended. Hogaboam and Perfetti presented evidence for this but since their dependent measure (reaction times to make judgements of ambiguity) has a strong memory component, it is not clear what the implications are for ongoing sentence processing.

Onifer and Swinney (1981) looked at frequency effects "on-line" using the same paradigm as Swinney (1979) and a 0 msec. delay. They chose ambiguous words that had a clearly dominant (more than 75% frequency of occurrence) and a clearly subordinate (less than 25% frequency) meaning and found no differential effects. Both meanings were accessed even when the sentence was biased toward the dominant meaning. But, although frequency effects weren't found at the offset of the word it is possible that a more thorough investigation of the time course of activation would reveal where and how frequency information is used. One possibility is that dominant meanings reach a greater degree of activation. This would mean that frequency information is encoded in the network in the form of higher resting levels of activation for dominant meanings. This would be reflected in more priming for dominant-related targets. At word offset, both meanings may have just passed their threshold and therefore seem to be equally activated. To determine if this were true, one needs to probe at a later delay.

Yet another hypothesis is suggested by the use of a different type of ambiguous word than has commonly been used in these studies. So far, only homographs (words that sound and are spelled alike but have different meanings) have been used. Another type of ambiguous word was used in the studies to be reported here - non-homographic homophones. These are words that sound alike but have different spellings as well as meanings (e.g., air-heir). Using this type of word has two advantages. It provides a more reliable measure for assessing frequency of occurrence of meanings than the use of homographs. The latter requires word association data - an indirect measure of frequency. Non-homographic homophones enable one to look up the frequencies in the Kucera and Francis (1967) word frequency norms.

A second advantage comes from the additional information that's available in the form of separate orthographic representations for the two words. It's possible that the separate orthographic paths may permit selective access. If one meaning has already been primed by context, access may be restricted to that path with the orthographic representation that is connected directly with that meaning. This mechanism is not available with homographs. There, both meanings are connected with the same orthographic representation (see Figure 1). Alternatively, this information from the orthography of the word may not be used in this way, so that either it is bypassed or else all orthographic paths from the same phonological representation are always accessed.

Finally, I was also interested in how far the automatic activation of meanings extended. Many ambiguous words actually have more than just two meanings. "Draft," for example, has all of the following meanings:

A. conscription process
B. breeze
C. beer
D. preliminary sketch
E. payment order

and those are just the <u>noun</u> interpretations. Are the more infrequent meanings activated as well?

In summary, then, I ran the following three experiments:

1) Frequency effects - the cross-modal priming paradigm was used with non-homographic homphones at a delay of 100 msec. from word offset. 100 msec. was chosen since it was expected that multiple access would still be occurring (Tanenhaus et al. (1979) reported that only the appropriate meaning was still activated at 200 msec. after the end of the word) but that the access process would be advanced enough to pick up frequency differences in level of activation if there were any. Alternatively, if separate orthographic representations were permitting selective access, that would be apparent at this delay, as well.

2) Context effects at initial access - design and materials for this are the same as in the previous experiment except that targets are presented at the beginning of the word. This experiment was undertaken to assess the effects of context as lexical access was just starting.

3) Activation of infrequent meanings - this experiment was similar to the above in design but the materials were different. Due to the difficulty in finding three-way ambiguous non-homographic homophones, homographs were used instead. Sentences were biased only toward the dominant meaning and targets were related to either the subordinate meaning or the third most frequent meaning associated with the homograph. Targets were presented at the zero delay to provide the most direct comparison with previous studies that had found multiple access.

Results

The results are presented in Table I (see next page) as reaction times in msec. Amount of priming is determined by taking the difference between the reaction time to the target and its control.

At 100 msec. multiple access was found for the non-homographic homophones. This indicates that the availability of separate orthographic pathways does not permit selective access and confirms the Onifer and Swinney finding that frequency differences do not lead to selective access. However, at 100 msec. there <u>is</u> a frequency effect in that the degree of priming for dominant meanings is greater in both the appropriate and inappropriate contexts. Apparently, dominant meanings reach a higher level of activation during access than subordinate meanings. This suggests that frequency information is coded in the lexical network in terms of higher resting levels of activation for frequently used meanings.

The results of the second experiment (Targets presented at the beginning of the word) reveal that context is having an effect before the access process has really begun. There is priming for the targets related to the appropriately biased meaning but not for those related to the inappropriately biased meaning. There is no effect of frequency. This demonstrates that context alone has a priming effect. And given that the first study shows that multiple access nonetheless occurs later, one can draw some interesting conclusions about the force of bottom-up processing in lexical access.

Context is able to prime the appropriate meaning of a word before enough phonological information has been obtained to recognize the word. Once the word is heard, however, this effect of top-down processing is overridden by the automatic process of lexical access. Bottom-up analysis apparently has priority here even when there is sufficient information available in the form of strong semantic constraints on probable senses of the ambiguous word.

The finding that context is priming is also interesting in light of the Seidenberg, Tanenhaus, Leiman, and Bienkowski (1982) study that indicated that there are two types of contexts: priming and non-priming. In their experiments, non-priming contexts produced multiple access and priming contexts produced selective access. Priming

contexts contained a semantically or associatively related lexical item prior to the ambiguous word. The results of the present experiments, however, indicate that contexts can be priming yet still produce selective access, suggesting that there was another reason for selective access in the Seidenberg et al. study. Another possiblity for this difference in findings concerns the nature of their priming contexts. The contexts in my studies either did not contain words that were strongly semantically or associatively related to the ambiguous word or contained them at a distance from the ambiguous word that was sufficient to make interaction unlikely. Perhaps related lexical items produce activation that is strong enough to overwhelm the automatic access process. In order to assess this hypothesis, one would need to use materials like that of Seidenberg et al. in a condition where targets are presented at word onset to allow a direct comparison with the results of the present study.

The results of the last experiment are problematical. In this experiment, words related to the second and third most used meanings of homographs were presented at word offset in sentences of dominant bias. Results indicate that neither meaning was primed (see Table 2). However, while the difference between related and control words was not significant, it was in the right direction. And, since all previous studies have shown that the subordinate meaning is activated under the conditions of bias that existed in these contexts, I have concluded that there is possibly a confound in this experiment. I am currently collecting subject ratings of the degree of relatedness between targets and their ambiguous words to determine whether poor stimulus-target relatedness obscured the priming effects.

Conclusions

The results of these studies taken in sum elucidate the interaction between top-down and bottom-up processing in lexical access as it occurs in sentence comprehension. Biasing contexts can act through the use of semantic constraints to prime anticipated meanings of words. Once the word has been heard, however, an automatic process of access is set into motion in which all the most likely meanings associated with a word are activated regardless of the initial priming due to context. This automatic access of multiple meanings is unaffected by the availability either of information about frequency of use or by potentially disambiguating orthographic information. Once accessed, though, meanings differ in the degree to which they are activated, with the dominant meaning being more strongly activated than the subordinate meaning.

Lexical access, then, is a process in which bottom-up information has priority, overriding the effects of higher-level information and suspending its use until the automatic process set in motion by the auditory signal is completed. Therefore, while top-down processing is essential for sentence understanding, comprehension is also so strongly tied to the stimulus that lower level analyses must be completed before semantic and pragmatic knowledge can have a decisive effect.

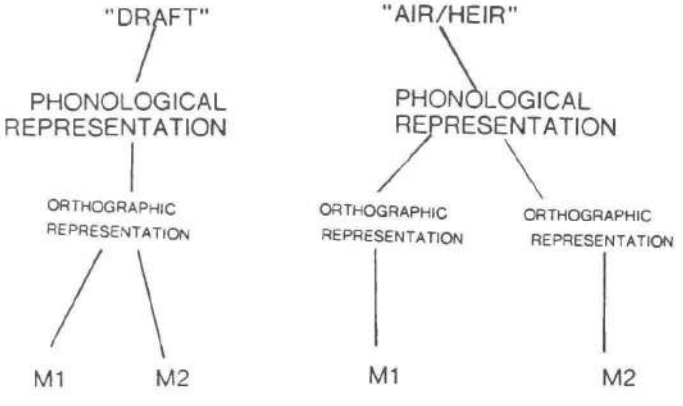

Figure 1

TABLE 1
Delay time : 100msec

FREQUENCY

	DOM		SUB	
	Related	Control	Related	Control
APP	766.5	831.2	786.3	798.4
	64.7		12.1	
INAPP	789.6	832.3	763.3	790.3
	42.7		27.0	

DELAY TIME : Beginning of Word

FREQUENCY

	DOMINANT		SUBORDINATE	
	Related	Control	Related	Control
APP	782.7	824	811.8	856.0
	41.3		44.2	
INAPP	789.0	775.8	754.0	759.0

TABLE 2

DELAY TIME : 0 mSec

TARGET TYPE

Related M2	Control	Related M3	Control
763	776	787	795

References

Collins, A.M., & Loftus, E.F. (1975) A spreading activation theory of semantic processing. Psychological Review, 82, 407-428.

Forster, K.I. (1979) Levels of processing and the structure of the language processor. In W. E. Cooper & E.C.J. Walker (Eds.), Sentence processing: Psycholinguistic studies. Hillsdale, N.J.: LEA.

Garrett, M.F. Word and sentence perception. In R. Held, H.W. Leibowitz & H.L. Teuber (Eds.), Handbook of sensory physiology, Vol. VIII: Perception. Berlin: Springer-Verlag, 1978, p. 611-625.

Kahneman, D. Attention and effort. Englewood Cliffs, N.J.: Prentice-Hall, 1973.

Kucera, H., & Francis, W. Computational analysis of present-day American English. Providence, R.I.: Brown University Press, 1967.

Marslen-Wilson, W.D., & Tyler, L.K. (1980) The temporal structure of spoken language understanding. Cognition, 8, 1-71.

Meyer, D.E., & Schvaneveldt, R.W. (1971) Facilitation in recognizing pairs of words: Evidence of a dependence between retrieval operations. Journal of Experimental Psychology, 90, 227-234.

Onifer, W., & Swinney, D.A. (1981) Accessing lexical ambiguities during sentence comprehension: Effects of frequency of meaning and contextual bias. Memory and Cognition, 9, 225-236.

Seidenberg, M.S., Tanenhaus, M.K., Leiman, J.M., & Bienkowski, M.A. (1982) Automatic access of the meanings of ambiguous words in context: Some limitations of knowledge-based processing. Cognitive Psychology.

Shiffrin, R.M., & Schneider, W. (1977) Controlled and automatic information processing: II. Perceptual learning, automatic attending, and a general theory. Psychological Review, 84, 127-190.

Swinney, D.A. (1979) Lexical access during sentence comprehension. (Re)consideration of context effects. Journal of Verbal Learning and Verbal Behavior, 18, 645-660.

Tanenhaus, M.K., Leiman, J.M., & Seidenberg, M.S. (1979) Evidence for multiple stages in the processing of ambiguous words in syntactic contexts. Journal of Verbal Learning and Verbal Behavior, 18, 427-441.