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CONTEXT EFFECTS ON LEXICAL PROCESSING DURING AUDITORY SENTENCE COMPREHENSION

On the Time-Course and Neurological Bases of a Basic Comprehension Process

Abstract. This paper presents an integrated view of the effects of context upon lexical access and lexical integration during sentence comprehension. The review incorporates evidence from both standard psycholinguistic and neuro-cognitive approaches. Along with this integrated overview, new hemisphere-specific processing evidence concerning context and lexical processing is presented. The evidence is taken to support a "modes of processing" perspective in the examination of sentence comprehension.

1. INTRODUCTION

Understanding the nature of lexical representation and processing constitutes one of the foundational issues in the study of sentence comprehension. A vast literature, spanning decades of research, has been produced on topics and issues related to lexical issues, resulting in a number of well-established findings but an even larger set of conflicting evidence and theoretical claims. The goal of this chapter is to present an integrated view of lexical access, lexical integration, and the time-course of the effect of context upon these processes. We propose to accomplish this with the aid of two specific levers (involving relevant new data): First, an examination of the neurological underpinnings of these processes and second, consideration of the issue of "modes" of processing. Ultimately, we believe that these considerations allow for an integrated view of lexical processing in service of sentence comprehension. In what follows, we first present some parameters that limit the domain of the field to be covered in this chapter, followed then by our examination of lexical processing and context effects.

2. SCOPE OF REVIEW / ANALYSIS

There are three tenets which guide the approach taken and the choice of evidence examined in this exposition. The first is that language processing in general is something that can be accomplished in a number of ways. Moreover, central to any understanding of the nature of the processes underlying language is a clear, detailed definition of the "type" of language situation - the parameters of language processing - that are under focal investigation. It follows from this that lexical access and integration can potentially be accomplished via varying processes in different situations. Thus, it is absolutely critical to carefully specify the: parameters and conditions focused on in any set of claims about the nature of lexical processing.

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with broader-scope (off-line) approaches in order to gain an integrated picture of all levels of processing; however, it is the on-line details that will largely differentiate among most current theoretical accounts of contextual processing and lexical access.

Finally, the third tenet guiding our approach is that it is only in the conjunction of traditional on-line behavioral processing evidence combined with relevant evidence from modern cognitive neuroscience (e.g., studies of focal brain-damaged populations, brain imaging, etc.) that the necessary leverage will be obtained to gain more definitive answers about the classic, central theoretical issues in the field.

In line with the above, this chapter will focus on the study of lexical processing during auditory comprehension. The processes underlying listening and of reading diverge and differ at numerous critical stages and detailing the differences and similarities between the two is considerably beyond the scope and length parameters of this chapter. In addition to focusing on the auditory domain, this chapter will also focus on comprehension of lexical information as examined within the context of ongoing sentence comprehension. While the processing of words outside of sentence/discourse contexts (i.e., in isolation, in pairs, etc.) holds obvious relationships to that found within standard sentence/discourse comprehension, the comprehension process is sensitive to critical processing parameters which are simply unavailable (and hence not utilized) in the processing of words outside of discourse/sentence settings. The link between the mechanisms underlying lexical processing as found in sentences and lexical processing as found in other settings awaits a far larger understanding of goals and parameters of cognitive processing in general.

3. THE EFFECTS OF CONTEXT ON LEXICAL ACCESS

Basic Issues and Evidence. The fundamental issue that has formed the basis of debate in the lexical representation / lexical, processing field has concerned the manner in which lexical information is made available to the ongoing comprehension process. While this has often been framed as an issue of 'Modularity vs. Interactivity' of information processing during comprehension (e.g., Fodor, 1983; Swinney, 1979; Marslen-Wilson and Tyler, 1982), each of these terms have come to 'cover' for a (surprisingly varied) number of claims about processing. We will thus avoid use of these specific terms at first here, focusing instead on specifically defined issues. We will be concerned with the question of how (and when) contextual material which occurs prior to a particular word in a sentence constrains the amount or type of lexical information about that word that is made availab a to ongoing comprehension. This is the aspect of the modularity-¡nteractkvity debate that is concerned with whether or not prior context has the ability to limit access to information 'stored with' a lexical item.[1] We will be concerned with the time-course of availability of (all or part of) such lexical information for further processing during ongoing comprehension. Ultimately, we will also be concerned with the degree to which specific lexical processes are susceptible to effects of expectations and predictions based on world knowledge and prior context. Alternatively, we will explore the degree to which these certain. lexical processes are fundamentally form-directed operations.

Our analysis in this chapter focuses on the processing of lexically ambiguous words, words in which the phonological form connects to more than one meaning. Such homophonic/homonymic lexical elements have traditionally constituted the major testing ground for the issues concerning context effects and lexical processing, as they provide individuable information (the distinct 'meanings' of the ambiguity) which can be separately addressed via contextual material. This, allows for empirical tests of when and how context may come to constrain the access to such information (See, e.g., work by Foss, et al 1988, etc.).

Studies examining the processing of lexical ambiguities during auditory sentence comprehension, in the absence of a biasing prior context, have nearly uniformly, demonstrated that. all meanings associated with the word form are momentarily accessed and made available for further processing (Onifer and Swinney, 1981; Picoult, J. & Johnson, M.K., 1992; Prather and Swinney, 1977; Seidenberg, Tanenhaus, Leiman, and Bienkowski, 1982; Simpson, 1981; Swinney, 1979; Swinney and Prather, 1989; Tanenhaus, Leiman and Seidenberg, 1979, among others). Thus, when no prior biasing constraints from world knowledge, lexical associates, plausibility, discourse context, etc. are present, access to all information stored with a lexical entry is made available to sentence processing for a short period. Note that there is standardly the inherent effect of relative frequency which may determine the order of availability of various meanings of lexical ambiguities; however, such frequency effects are neither constraining nor precluding effects (i.e., the less frequent meanings are still made available for further processing; see more on this, below).

Studies examining the processing of lexical ambiguities during auditory sentence comprehension in the presence of prior context are slightly more varied in the interpretation of their findings. The vast majority of such work has regularly and repeatedly demonstrated, across a large range of `prior contexts', that context does not restrict immediate or initial access to lexical information. This is nearly universally true in research which has employed temporally-sensitive tasks which have been demonstrated to have only a minimum of demand-characteristics that force interactions with the lexical access process itself. Thus, for example, unrestricted, exhaustive initial access of meanings for lexical ambiguities has been found even in the presence of prior contexts which place strong and definitive constraints on their interpretation in terms of: 1) Syntactic category (e.g., Prather and Swinney, 1977; Tanenhaus, Leiman and Seidenberg, 1979), 2) Semantic-associative contexts (e.g., Swinney, 1979; Onifer and Swinney, 1981; Simpson, 1981; Seidenberg, Tanenhaus, Leiman and Bienkowski, 1982; Picoult & Johnson, 1992; Love and Swinney, 1996, Conseco-Gonzalez (her dissertation); Miyake, Just & Carpenter, 1994; among others), 3) Highly restrictive semantic-associative sentential contexts (e.g., Swinney, 1991), and 4) Discourse contexts (e.g., Swinney, 1982). This effect also holds, regardless of whether the biasing context appears earlier in the same sentence as the ambiguous word, or in a prior sentence in a larger discourse (e.g., Swinney, 1979). Similarly, it has been shown that a patient population which has well-defined and well-known inabilities in utilizing context - chronic schizophrenics - demonstrates their `context problems' only at a point 'downstream' from initial access of all the meanings of a lexical ambiguity, not at the point of access (Onifer, 1980). This, therefore, supports the view that the locus of 'prior context' effects on lexical ambiguity is at a point following initial access of

all information stored with that entry. Finally, we note that this same pattern of exhaustive, form-driven, context-independent access has also been demonstrated in on-line studies of processing in pre-school age children (Swinney and Prather, 1989; Love, Swinney, Bagdasaryan & Prather, 1999).

This relatively large range of evidence has come from a number of different tasks - cross-modal lexical priming, auditory ERPs, immediate judgment tasks, etc. - which have examined context and ambiguity processing in normal, fluent speech. In all, then, studies of fluent auditory language processing have repeatedly demonstrated that whenever a phonetic form of a word is encountered there is immediate and unconstrained access to all information for that word, even in the face of a wide range of strongly constraining, prior-occurring, contexts. There is evidence, however, that as early as 200-300 msecs following initial access, biasing contexts may begin to have constraining effects [2]. Our examination of the neurological underpinnings of lexical ambiguity access, resolution and context effects begins with these established findings.

In what follows immediately below we briefly present a summary of a small portion of a recent study that replicates the basic findings discussed above. We present it in some detail so as to allow for both a specific set of findings to carry through in further discussion, and a specific example to consider throughout our consideration of these effects.

Love and Swinney (1996) present an examination of effects of context and structural processes on lexical ambiguity access and processing. The following is a summary of the methodology employed in this study:

3.1 Methodology

A Cross-Modal Lexical Priming (CMLP) task was employed, using a matched-probe configuration (Swinney, Onifer, Prather, and Hirshkowitz (1979) [3]. Participants in the part of the study to be described here were 51 non-neurologically-involved college students, who heard sentences such as:

The professor insisted that the exam be completed in ink, so Jimmy used the new pen that his mother-in-law recently purchased because the multiple colors allowed for more creativity.*

There were 40 such experimental sentences (along with 40 structurally similar 'control' sentences and 10 practice sentences). All sentences were recorded (in pseudo-random order on counterbalanced scripts) by a male speaker at the rate of approximately 5 syllables per second. The asterisk (*) indicates position at which the experimental and control visual probes appeared during the sentence; only a single sentence and single probe at a single position was presented to any one participant; conditions were counterbalanced across a series of scripts and subject groups [4]. Participants 'named' each probe word that appeared and RT to voice-onset of these 'naming' responses was recorded. The biasing contexts in the experimental materials were created followed the criteria employed by Tabossi (1988) to establish a bias toward a strong 'aspect' of the *a priori* more frequent meaning of the ambiguity, (under these criteria, a minimum of 75% of 12 judges agreed on intended

aspect of meaning of the ambiguous word in the sentence, etc.). In a separate pretest, the 'related' visual probes were created by first obtaining associations to the ambiguous word. Uniformly agreed-upon associates related to each interpretation of the ambiguity were chosen as the 'related' probes, and these were matched with 'unrelated control' probes (based on *a-priori* reaction times taken in an isolated word `naming' task, performed with over 50 subjects from yet another pretest) Thus (to follow the above example) associated probes related to each of the meanings of the ambiguous word 'PEN' were chosen (e.g., 'PENCIL' and 'JAIL'), along with reaction-time-matched control words. Experimental and control probes were also equated for both 'goodness-of-fit' to the sentence as heard up to the point the probe appeared (this involved a rating scale ranking of goodness of fit of the probe to the 'preceding' sentence fragment) and for 'relatedness-of-probe-to-sentence' (again, a rating scale).

3.2 Results

The critical findings were: A main effect for Probe Type (related vs. control) ($F(1,47) = 14.844$, $p=.001$), which did not interact significantly with the Ambiguity-Meaning factor (Primary vs. Secondary). Planned *a priori* comparisons performed on the related vs. control probes for each of the Ambiguity Meanings demonstrated a significant priming effect for both the Primary Meaning - PENCIL ($t_{50}=2.242$, $p=.015$) and for the Secondary Meaning - JAIL ($t_{50} = 1.805$, $p=.038$)

The mean reaction times for 'control' and 'related' probes for both primary and secondary interpretations of the lexical ambiguity) can be seen in the following:

Ambiguity Meaning :	Primary (PENCIL)	Related probe: 521 msec
		Control probe: 533 msec
	Secondary (JAIL)	Related probe: 529 msec
		Control probe: 537 msec

This study thus replicated the long established finding of contextually independent, form-driven initial access for lexical information. [6,7]

We now turn to considerations of the neuro-biological mechanisms that might underlie both the contextually-independent, form-driven access and subsequent 'meaning resolution' evidence seen in this and many similar on-line behavioral studies of the effects of context upon the processing of lexical information during sentence comprehension.

4. NEUROLOGICAL BASIS OF LEXICAL PROCESSING

4.1 Lesion evidence

Evidence from the processing of lexical ambiguities in patients with focal lesions provides vehicle via which an understanding of aspects of the behavioral evidence derived from non-neurologically involved populations (and discussed above) can be refined and extended. In particular, we note that evidence concerning the processing

of lexical ambiguities in auditory sentences by patients who have Broca's aphasia provides an interesting contrast to those for non-lesioned patients (and to those with lesions in other brain areas).

Broca's aphasia, is standardly associated with lesions in and around the lower portion of the left frontal lobe of the cortex (more particularly, the opercular and triangular portions of the inferior frontal gyrus, including the foot of the third frontal convolution and extending into subcortical white matter[8]). Difficulty in both the articulation and production of speech, accompanied by subtle difficulties in comprehension accompany the syndrome diagnosis. Patients with damage in and around these areas typically produce, at best, labored speech, which is poorly articulated and telegraphic in nature (typically involving omission of many 'function' or 'closed-class' words) and display comprehension problems with complex syntactic structures, at both on-line and off-line levels of analysis.

Swinney, Zurif and Nicol (1989) presented a population of Broca's aphasics, non-impaired age-matched control subjects, and Wernicke's aphasics (where damage is in the left temporal lobe of the cortex - in areas considerably removed from the damage found in Broca's aphasia) with auditory sentences containing lexical ambiguities. These ambiguities were presented in sentential contexts that were biased either toward the *a priori* primary interpretation of the ambiguity, or the *a priori* secondary interpretation of the ambiguity. In a CMLP study designed similarly to that presented just above (except that a 'lexical decision' task rather than a 'naming' task was utilized in this study, and the sentences were considerably shorter in overall length), it was found that the non-impaired control population demonstrated immediate access for both meanings of the ambiguous word (as shown by significant ($p<0.05$) priming scores for probes related to each meaning) independently of the presence of a biasing sentential context. Similarly, the Wernicke's aphasic population displayed the same pattern of effects (significant priming for words related to each meaning of the ambiguity, independent of contextual bias) Thus, brain damage per se (i.e., brain damage at just any randomly chosen location) does not change these characteristics of lexical access. Importantly, however, (and in contrast, to the findings just reported), the patients classified as Broca's aphasics demonstrated a different pattern of results. For the Broca's aphasics, only the primary (a-priori most frequent) meaning of the ambiguous word was found to be significantly primed ($p<.05$) immediately after that word was heard in a sentence, regardless of the direction of the bias of the prior context in those sentences. At least two conclusions can be drawn from these results. First, brain damage - either in Broca's or in Wernicke's areas - does not change the contextually-independent nature of lexical access; contextual information did not act to limit initial access in either population (or in the age-matched control). Second, persons with damage to Broca's area apparently have initial access to only the most frequent interpretation of ambiguous words. This has been interpreted as indicating that certain lexical information (and certainly that which is associated with a less-frequent interpretation) may have temporally protracted (slower-than-normal) 'rise time'. The finding that certain types of lexical information may have a slow 'rise-time' is not an unusual finding. Work with both very young children (Swinney and Prather, 1989 and dyslexics (Swinney, 1982) have found evidence suggesting that certain aspects of lexical information may be

slower than others to have effects on on-going sentence integration. Note, however, that this finding is not at all in conflict with the conclusion that context does not, limit initial access. The issue there is whether context prevents access to contextually-unrelated information for words - i.e., that it by-passes or constrains form-driven access. The fact that some information is slower than other information to be made available, usable, (or even detectable), should not be surprising, and is certainly separate from considerations of the initial effects of context on lexical information access. Importantly, however, these findings suggest that the cortical (and sub-cortical) regions of the left hemisphere associated with Broca's aphasia may have a role in the time-course of making aspects of stored lexical information available to more integrative, ongoing, sentence processing.

Several related studies have supported this interpretation of the role of Broca's area in lexical processing. For example, Swaab, Brown, & Hagoort, (1997) employed an ERP methodology to examine the processing of lexical ambiguities in Broca's aphasics in auditorily presented sentences. In this study the status of activation of meanings for the sentence final ambiguous word was inferred from the amplitude of the N400 to related targets that were presented at two different inter-stimulus intervals. The ERP evidence was interpreted to indicate that Broca's aphasics, in contrast to elderly controls, were not successful at selecting an appropriate meaning based on context for the ambiguity immediately (the short ISI condition), but that at the long ISI the patients were able to do so. While there are always concerns over interpreting data obtained from material presented in sentence-final and trial-final position (strategic end-of-sentence wrap-up effects, etc.), these data at least fit with a view that contextual integration of lexical material may be protracted in these patients, again suggesting that the neural substrate underlying Broca's aphasia may be critical for normal rapid lexical access and integration.

More directly to the point, Prather. Zurif. Love and Brownell (1997) investigated the 'protracted lexical activation' hypothesis concerning the neural region subsumed by Broca's area in a study of the time course of lexical activation and priming. They employed a continuous-list priming paradigm, in which words to which subjects make lexical decisions appear in a continuous (non-paired, sequential) list. Hidden within this list, however, are some sequentially-contiguous words which constitute semantic prime-target pairs). This technique is one of the few ways in which non-sentential word priming effects can be studied without special pair-wise 'control' strategies arising due to methodology. In the study, they manipulated the temporal delay (ranging from 200-2100 milliseconds) between successive words in the list. In a single-case study, a classic Broca's aphasic subject demonstrated reliable automatic semantic priming only at the relatively long ISI of 1500 msec. (This was in stark contrast to non-neurologically involved elderly control subjects and the Wernicke's aphasic also profiled in this report, who prime at relatively short inter-stimulus intervals - typically beginning at 500 msec.). Thus, this Broca's aphasic retained the ability to access lexical information when allowed sufficient time to do so.

Thus, based on lesion evidence, it appears that the (left-hemisphere) neural substrate underlying Broca's aphasia (Broca's area) may be critically involved in the well-established effects found in the on-line sentence processing literature for 'non-neurologically involved' listeners: namely, the rapid/immediate access of the all (including the less frequent) of the interpretations of an ambiguous word

independently of context. In addition, there is some evidence that damage in and around this area may also be involved in subsequent resolution of these `meanings' to a single 'contextually appropriate' interpretation, again, possibly related to the use of this substrate in promoting and regulating the rapid availability of lexical information to ongoing comprehension processes. Damage to the cortical (and perhaps subcortical) region in and around Broca's area appears to undermine both the ability to make all information stored with a word `immediately' available for further sentence processing[9] and to also disrupt the subsequent integration of those word meanings with context. In order to further consider the neurological underpinnings of this latter issue, we turn briefly to a description research on the effects of brain lesions in subcortical tissue with connections to cortical tissue, including Broca's area.

A growing body of work has developed concerning the role of the subcortical tissue in and around the basal ganglia (but not including the thalamus) (i.e., the caudate nucleus, putamen, internal capsule; often termed striato-capsular area). Much of this research, while not primarily examining auditory comprehension, has come to suggest that this neural substrate in the left hemisphere has a neuro-regulatory role in lexical-semantic processes, particularly with regard to 'controlled' or 'attentional' forms of dealing with lexical information (e.g., Crosson, 1985; Copland, Chenery & Murdoch, 2000). Of particular relevance is recent work by Copeland (2000), in which he used a CMLP paradigm to investigate the processing of lexical ambiguities in a biased sentential context in patients with left-hemisphere (language-dominant hemisphere) non-thalamic subcortical lesions. He found two important results relevant to our concerns. First, the left-hemisphere subcortical lesioned patients failed to maintain a selective facilitation for (failed to demonstrate continued significant priming for) the contextually appropriate meaning of the ambiguity, thus implicating this brain region in support of attention-based control, maintenance and integration of lexical-semantic sentential information based on sentential context. Second, he demonstrated that patients with these same lesions failed to utilize discourse-level information to select relevant meanings for words. It is worth noting in this regard that dopamine dysfunction in this same general brain region (basal ganglia and cingulate) has been implicated in abnormalities associated with semantic associative activation (Posner & Raichle, 1994; Fuentes & Santiago (1999). This, of course, underscores the work reported above by Onifer (1980) on CMLP and the locus of context effects in sentence processing in individuals with chronic schizophrenia.

In all, it appears that the striato-capsular subcortical region of the language-dominant hemisphere, with afferent input from (among other cortical areas) Broca's area, has a major role in integrating and maintaining activated lexical information during auditory sentence comprehension. Thus, while Broca's area may be involved in making lexically activated material available in a timely manner to ongoing sentential integration processes, the striato-capsular region appears involved in integration and maintenance of contextually relevant interpretations.

4.2 Contributions of the left and right hemispheres in processing lexical ambiguities

There is a very small but relevant body of research examining the individual (independent) contributions of the left (LH) and right (RH) cerebral hemispheres in non-neurologically involved individuals to lexical processing and context effects during sentence processing. This literature makes it clear than it is not only the language-dominant (typically, left) hemisphere which has a role to play in the activation and integration of lexical information in service of auditory sentence understanding. In a study involving non-brain-damaged subjects, Faust & Chiarello (1998) investigated hemisphere asymmetries in processing lexical ambiguity within a sentence context. Sentences containing sentence-final ambiguous words (biased toward a single meaning) were presented, followed by a hemi-field lateralized 'lexical-decision' target word, which was related to either the contextually relevant or contextually incongruent meaning of the ambiguous word. They found that right-visual-field-presented contextually congruent targets were primed, while RVF incongruent targets were not. In contrast, in the left visual field both the congruent and non-congruent targets were primed, regardless of sentence context. Again, employing an end of sentence-ambiguity hemifield-target priming paradigm, Titone (1998) also found evidence consistent with the view that there is differential sensitivity in the cerebral hemispheres to meaning salience and context. Both of these studies, however, employed end-of-sentence ambiguity targets, something that has been called into question due to end-of-sentence wrap-up effects in other studies of sentence processing (see, e.g., Balogh et al, 1998).

Love, Bouck, Hald, Hickok, Swinney (in prep) have recently conducted a study involving 66 native English right handed individuals which also explored possible hemispheric asymmetries in lexical ambiguity resolution in auditory sentence processing employing a CMLP experiment with divided field presentation of visual priming target probes. In this study lexically ambiguous words were embedded in (not at-the end of) auditory sentences which contained strong a-priori contextually biasing material (As in the example given previously in this paper concerning the ambiguity 'PEN'). Visual lexical decision targets related to the primary and secondary meanings of the ambiguity were presented to either the LH or RH. These words were presented in normal left-to-right word format, to the left or right extra-fovial area. They were presented such that the innermost (most nasal) letter of the word presented to each visual field fell at least 2° from center. Thus, only one (L or R) visual cortex initially received and processed this visual information. These words were presented either immediately after hearing the lexical ambiguity in the sentence, or 750 msecs later (in both cases, during ongoing processing of the sentende).[10] Analysis of these data demonstrate that in the LH, priming for both interpretations of a lexical ambiguity is significant at the point immediately after the ambiguity was processed. However, at this same immediate test point, only priming for the contextually-relevant (which also was the most frequent) interpretation of the ambiguity is demonstrated in the RH. However, when tested at the longer (750 msec.) ISI, the LH demonstrates priming only for the (more frequent) contextually relevant interpretation, while the RH demonstrates priming for both interpretations.

Overall, this body of work is thus quite in accord in the conclusion that the LH is involved in the initial rapid access of ALL interpretations of a lexical item, even in the face of prior biasing context. This, of course fits well with the findings from the

lesion evidence, presented above. Relatedly, it appears that the LH is involved in the rapid post-access selection (resolution), maintenance, and integration of contextually relevant meanings of words. The RH appears to have the capacity for slowly activating and maintaining the less-frequent (and in these cases, contextually-irrelevant) interpretations of word senses - something that may come into play, for example, in re-processing the sentence when the wrong interpretation of the ambiguous word was chosen early in the sentence.

It is worth noting that exists a separate literature on brain lesioned individuals that supports this view of the role of the RH in lexical processing. Tompkins, Baumgaertner, Lehman, Fossett (1997) conducted a study with RH Damaged individuals involving auditorily presented sentences with sentence-final lexical ambiguities. They employed an interference task involving the presentation of visual targets one second following the end of the sentence. In this, they report that the RH Damaged individuals (as opposed to non-impaired controls) demonstrated difficulty in suppressing the contextually inappropriate meaning of the ambiguities. The authors argue that this lends support to the role of the right hemisphere in maintaining alternate the (secondary) interpretations of lexical ambiguities.

5. SUMMARY

A clear story concerning the nature and time-course of context effects on lexical processing during auditory sentence comprehension only emerges via the integrated examination of evidence from studies of lesion patients, studies involving hemispheric isolation, and the general behavioral on-line processing studies (which were performed independently from any brain-basis concerns). It appears from all of this that the left and right hemispheres work together to produce the findings that populate each of those literatures in isolation - findings that in isolation have often to be at variance.

Overall, it can be seen that context does not place prior constraints on lexical access during auditory sentence processing. All information associated with an auditory lexical form is made available to ongoing sentence processing when it is first encountered in an auditorily presented sentence (and at any time that it is re-encountered during the same discourse, see Endnote 7). Contexts (of every type thus far tested) have their effects only following this initial exhaustive access process. The role of the Left Hemisphere in this process appears to be that which underlies this initial form-driven exhaustive lexical access and the subsequent rapid post-access effects of context upon this accessed material during ongoing auditory sentence comprehension. Both studies of the LH and RH in isolation and of the processing found in patients with focal brain lesions, supports the view that, immediately upon 'hearing' an ambiguity, there is rapid and exhaustive access of all meanings of the ambiguity made available in the Left Hemisphere, independently of prior contexts. It appears from lesion evidence that the brain tissue in and around Broca's area (anterior, frontal lobe, cortical areas of the LH) is deeply involved in the exhaustive, form-driven, fast-acting aspect of lexical access that has been so often demonstrated in studies of 'normal' auditory processing involving lexical ambiguities. Subcortical areas (nonthalamic basal gangular regions) in support of this cortical region appear critically involved in the rapid, contextually-directed

selection and maintenance of a single interpretation of lexical information, an interpretation that is necessary for ongoing sentence interpretation. When these LH areas of the brain are undamaged, and no re-processing of information is necessary, it appears that these subcortical regions are primarily responsible for the course of information processing that typically determines auditory sentence comprehension (in so far as lexical processing and contextual integration are concerned).

However, because of the very rapid nature of the process which eventuates in choice of a single lexical meaning for a word (and apparent suppression of other meanings[11]) in the left hemisphere during the processing of auditory sentences, two things hold. First, the left hemisphere typically produces an integrated interpretation of material before the RH does. As such, this LH interpretation is used in all further discourse processing (NB: this would follow from most models of the resolution of competing solutions, such as in horse-race models; the LH interpretation is the 'winner'). Second, when 'repairs' in sentence processing are required (e.g. as when re-interpretation is required if an ultimately 'incorrect' meaning of an ambiguity is initially 'chosen'), it appears that it is only the RH which maintains 'alternative' interpretations which allow recovery of correct meanings.[12]

Similarly, when the LH is damaged (as in Boca's aphasia, etc.) lexical-contextual processing must (and apparently does) rely to some extent on lexical processing from the RH. Thus, overall, the RH appears to play an important potential role in auditory sentence interpretation, and, in particular, in the interpretation of context effects during lexical processing. Thus, there are different potential 'modes' of processing that may cause different processes to be called into play in such auditory lexical processing.

The RH appears to make 'all' meanings of ambiguous words available, but only after they are already available in the LH (which may account for the apparent 'slow rise time' of secondary meanings found for ambiguities in Broca's aphasics; if not for the RH, it is possible that, in some cases, these less frequent meanings might not 'arise' at all). However, as suggested above, this effect is not reflected in the processing required in most `standard' on-line studies of normal sentence processing. Thus, it appears that while the RH actively processes lexical (and perhaps sentential) information, it may have little to no contribution to rapid first-pass analysis of language in sentence processing conditions involving non-brain-damaged individuals.[13] However, re-processing and re-interpreting is a common part of language comprehension - for reasons ranging from those as mundane as 'lack of attention' or 'conflicting contexts' to those as profound as 'brain-damage'. Thus, it seems the RH will often have a role to play in lexical/sentence processing. And thus, while the above exposition in this paper appears to capture much of what we know and have evidence for concerning lexical access and context effects rapid, first-pass auditory sentence interpretation processes, it is only part of the larger story. An understanding of all of the ways in which language processing may take place is critical to any overall model of comprehension. And these clearly often go well beyond initial, unrepaired, rapid first-pass analysis. Which brings us to:

6. A FINAL CONSIDERATION TOWARD UNDERSTANDING LANGUAGE COMPREHENSION: THE CONCEPT OF *MODES OF PROCESSING*

There is, of course, some research in existence that has not been interpreted to support the integrated story we have just presented. Evidence exists which, for example, has been claimed to demonstrate prior-constraint (predictive) effects of context upon lexical access. In nearly all cases, when the initial tenets which we briefly presented to begin this chapter are carefully considered (e.g., no intention to account for processing in different (i.e., visual) modalities; or, no intention to account for processing evidence derived from isolated word studies; or, no intention to be concerned with evidence obtained via tasks that have demand characteristics that force integration of context in the very measure obtained [14]; etc.) the critical reasons that 'different' interpretations are sometimes given can typically be discerned. However, it is a Herculean (and likely endless) task - and certainly not one possible in the constraints of this chapter - to report on each such study, and explain each basis for interpretive difference.

It has become clear to us in investigating these various accounts carefully that some seemingly subtle processing differences can make an enormous difference in terms of the form that data and apparent interpretations take. As they say - the devil is in the details. Rather than attempting to explain each detail here, we will make a brief presentation concerning what we have come to understand as the critical characteristic(s) that need to be considered in all such enterprises.

Primarily, in order to make a coherent story of any of the sentence processing literature (whether aimed at lexical, contextual, structural or discourse processes) the field (language processing) must adopt the theoretic of a 'modes of processing' account of language. What is implied in this is that there are many ways in which we accomplish language processing, and without precise understanding of ALL of the characteristics of EACH such 'way' we are doomed to continue contrasting and arguing, over interpretation of data that are as deeply different as are apples and pianos (merely employing the metaphoric contrast of apples and oranges doesn't accurately portray the diversity to be found in the language processing field). The concept of 'mode' obviously covers a lot of ground. We have dealt some key characteristics of different modes earlier in this chapter (modality, whether in sentence context or not, etc.) However, a number of exceedingly subtle differences in processing situation are also important. For example, work in our lab over the past 4-5 years has demonstrated that a variable as simple as the rate of information input in comprehension vastly changes both the `demand' characteristics of several standard tasks typically used to study lexical and structural processing as well as the way in which the comprehension process itself is performed. And, this involves variation of 'rates' of processing throughout a range standardly considered 'normal'. Similarly, modulations in processing as slight as adding regular and consistent noise to the speech signal, appears to change (in marked *ways)* the underlying on-line manner in which processing is typically performed on speech stimuli in sentences.

Thus, it should not come as any surprise that experimental conditions can be found in which it appears that context can be used to 'predict', and thus limit, selection of lexical information. Simply put, humans do have the cognitive capacity to predict things. For example, when subjects are encouraged by experimental task demands to anticipate goals, outcomes, or upcoming events (either explicitly or

implicitly), they will and can make such predictions. A careful perusal of the language processing literature will discover a large array of conditions which provide such task demands.

However, the overwhelming majority of studies examining auditory sentence/discourse comprehension in which the task demands do not encourage prediction (and where the experimental task is sufficiently sensitive to detect subtle on-line processes) have clearly revealed that lexical access is a form-driven, context-independent process. Rather, prior contexts have been shown to only have effects following initial access to stored lexical information. Critically, it is precisely this normal (rate and task), fluent 'Mode of Processing' that we are attempting to model in our studies of language comprehension. In such a 'mode', the details of the processing of lexical and contextual material in sentences, as well as their neurological underpinnings, appear consistent and robustly replicable.

There are, as noted above, alternative 'modes of processing' that may be engaged in certain language processing conditions. Whether the robust findings reported here for the Fluent Auditory Mode of processing will also account for the processing employed in some of these other situations remain an empirical issue. But, it is only by carefully detailing the modes of processing investigated in each and every case that will we discover the answer.

7. AFFILIATIONS

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8. NOTES

[1] NB: This is not a question concerning whether prior context ultimately constrains the lexical information used in a final interpretation of a sentence; the answer to that question is transparently obvious-it clearly does so. This is, rather, a question concerning WHEN it does so.

[2] There are, of course, some studies that have reported findings in disagreement with this general summary; these will be discussed below under the heading 'modes of processing'

[3] See Nicol, Fodor, Swinney, 1994; Swinney, Prather and Love (2000;endnote 1), Swinney, Nicol, Love & Hald (in press, and1997) for discussion of various design-types, and their relative advantages and disadvantages, in CMLP studies.

[4] We present here only results for the first of several probe positions tested in this study; the later probe positions examined an entirely different aspect of processing - canonical structural re-ordering - which is beyond the scope of the current review.)

[5] These controls were in response to issues originally raised in papers by McKoon and Ratcliff (1994; 1996), which, however, have since been demonstrated to be unfounded concerns (see Nicol, Swinney, Love and Hald, 1997).

[6] Note that the absolute numerical value of priming in these types of studies is, as always, uninterpretable; the absolute size of priming to probes is influenced by all items in the sentence (including the context itself), and hence priming for the contextually related probe is often numerically larger than that for the probe to the contexualy chosen meaning. Thus, absolute priming size is irrelevant and uninterpretable in these studies (here, at least, size doesn't matter!). It is only as an existence proof (the

existence or lack-thereof of a priming effect for probes related to each interpretation) that ilas interpretable substance. (See Swinney, 1979,1981,1982 for discussions of this issue).

[7] Even after a "contectually relevant" meaning of a lexical ambiguity has been chosen during sentence processing, when the system is presented again with the homophone, ALL meanings are again momentarily accessed (Love & Swinney, 1998).

[8] See Swinney, 1999; Dronkers, 1996; Friederici, 1995,among many other, for more details and discussion concerning the precise substrates typically associated with Broca's aphasia)

[9] Note that this seeming immediacy of availability of 'all meanings' of an ambiguous word for non-neurologically involved individuals may simply be a 'relative immediacy'. That is, it may be that we currently have no task with sufficient sensitivity to detect very small differences in the time-course of activation of meanings of an ambiguous word that might always exist, even in 'normal' populations. It may thus be that damage to Broca's area merely exaggerates existing differences that are too subtle to detect in persons without damage to that neural area. This, however, does not lessen the conclusions concerning the impact and role that this neurological substrate plays in allowing rapid availability of all meanings of a word to ongoing sentence processing operations.

[10] These timings were chosen based on earlier visual hemi-retinal priming paradigm studies of visual (isolated) word processing by Burgess and Simpson (1988) which had demonstrate that the LH provides activation of multiple interpretations (primary and secondary meanings) of ambiguous words immediately upon viewin the word. However, by 750 msecs later, only the primary (more frequent) interpretation of the ambiguity was actively maintained (primed). In contrast, the RH appeared to initially only have access to the more frequent interpretation of an ambiguous word, and "exhaustive" availability of both meanings of an ambiguous word (as measured via priming) at longer temporal delays (750 msecs.). Thus, in this instance, both the visual and the auditory studies vector to the same findings.

[11] See, for example, works by Gernsbacher and Faust(1991) or Friederici, Steinhauer, Mecklinger & Meyer (1998) for discussions of and evidence for such possible mechanisms.

[12] Such need for reprocessing can be seen, for example, in classic psycholinguistic demonstration materials such as: "The old man couldn't find his glasses in the dimly lit room, but finally found them in the comer, filled with wine".

[13] For more on first-pass processing issues, see, e.g., Friederici (1995) or Hahne and Friederici (1999)

[14] See, for example, discussions of such tasks in Swinney, Prather and Love (2000) and in Swinney, Nicol, Love and Hald (a. in press; b. 1997)

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