Online Examination of Language Performance in Normal and Neurologically Impaired Adults

Lewis Shapiro
San Diego State University, CA

David Swinney
University of California, San Diego

Susan Borsky
Florida Atlantic University, Boca Raton and San Diego State University, CA

This article describes how we and others have exploited online methodology to investigate normal and disordered language processing in adults. Online tasks can be used to measure effects occurring at various temporal points during ongoing processing and are often sensitive to fast-acting, automatic processes, as well as to processes that rely on the integration and interaction of several types of information. Online tasks can be compared to their offline counterparts, tasks such as sentence-picture matching, categorization, word generation and repetition. These tasks are often used by clinicians as part of their assessment and treatment repertoire and measure effects observed at the end-points of perhaps several processes. They can thus mask a patient's strengths (and weaknesses) in any single area, including subcomponents of the language domain. We review several online lexical and syntactic processing experiments and end with a discussion of the clinical benefits of this work.

There is now overwhelming evidence that the language processing system can be described, and perhaps even partially explained, by detailing the operation of components such as lexical access, syntactic parsing, discourse processing, and the like. The fact that language processing does not entail a single, unitary operation requires experimental techniques that can probe the system *locally* as component operations are unfolding over time. The techniques that allow the investigator to probe the system locally are often described as *online* tasks. In this paper we describe how we and others have exploited such techniques to help investigate normal and disordered language processing. Online tasks can be used to measure effects occurring at various temporal points during ongoing processing and are often sensitive to fast-acting, automatic processes, as well as to processes that rely on the integration and interaction of several types of information. One major question confronting the clinician-researcher is the degree of independence or dependence of the various components of language processing; online methodology allows us to investigate this question, and we will give our take on the answer to this and other questions in what follows.

Online tasks can be compared to their *offline* counterparts, tasks such as sentence-picture matching, categorization, word generation, repetition, etc. These tasks may often be used by clinicians as part of their assessment and treatment repertoire. It is fairly apparent that such offline tasks require a patient to consciously reflect on a decision (e.g., "What does this sentence mean, and, does this picture match what I just heard?"). Similarly, these tasks often involve problem solving (e.g., Question: "Is an ostrich a bird?" Answer: "Well, it has wings, but I don't think it flies, and it certainly doesn't look like most birds"). Clearly, they are affected by memory and attentional demands. In principle, then, offline tasks measure effects observed at the end-points of perhaps several processes; certainly they involve more than just the processes used in language comprehension or production, per se. They can thus mask a patient's strengths and weaknesses in any single area, including subcomponents of the language domain.

To see what we mean, consider here a relatively simple clinical scenario. You are confronted with a patient with obvious word-finding difficulties, and you need to design a treatment plan that best exploits the patient's strengths while, perhaps, circumventing her weaknesses. There are many possible logical antecedents to this word-finding problem, and discovering the one that underlies the problem might have implications for diagnosis and treatment. For example, perhaps the patient does not have knowledge of the words that she finds difficult to produce. If so, then perhaps training new concepts and extending lexical knowledge would be appropriate goals for treatment. Perhaps her knowledge is "fuzzy." If so, strengthening existing lexical knowledge by focusing on familiar words and their relationships to other words would be a goal. Perhaps her lexical knowledge is intact, yet the mechanism responsible for computing that knowledge is impaired. In this case, then, stimulating lexical access would be important. Or perhaps the lexical access mechanism is generally intact, yet the complex task of asking her to generate a word when faced with the additional demands of understanding task directions, visually examining a picture or object, and remembering the stimulus interacts with the output of lexical access, resulting in poor word-finding performance. In this case, you might plan a treatment program that initially attempts to train strategies that minimize cognitive demands. As one can see from this brief scenario, a test that simply requires a patient to generate words when confronted with pictures or objects might very well mask underlying deficits. Herein lies the promise of online tasks: They "zero in" on the normal operation of language processing and allow us to learn about deficits, about fundamental sparing and loss, and hence could help us to devise focused and efficacious treatment programs.

That said, we describe online tasks and discuss their strengths and limitations. We will primarily focus on two online tasks—cross-modal priming (CMP) and cross-modal interference (CMI)—tasks that we have used quite successfully and that we think allow a minimum of tampering with normal language processing. We show what these tasks have revealed about both normal and brain-damaged lexical and structural/syntactic processing. During our journey through the literature and our own work, we highlight various issues in normal and disordered language processing that online methodology has allowed us to investigate, with some success. Our paper is organized in three sections: lexical processing in sentences, structural processing, and the clinical relevance of this work.

Lexical Processing

A fundamental question in lexical processing is how words (e.g., their meanings, their structural properties) are accessed during normal sentence comprehension. One model of this process has been dubbed the *highly interactive* model of lexical access. Essentially, this model holds that all lexical processing is achieved through the interaction of any and all information the listener has at his/her command at any particular point in time. Consider what happens if a person were to hear the sentence fragment:

"The stamp is on the _______."

This interactive model claims that, even before the end of the fragment, the listener would have processed context that would direct him/her to predict that the upcoming word in the sentence would likely be *envelope* (as in: "The stamp is on the envelope"), because that is the most likely thing that a stamp would be on. In fact, *envelope* is a typical response found to this fragment via the offline cloze task wherein subjects are given a sentence fragment and asked to consciously guess the identity of the next word. Under the interactive model, the system *predicts* upcoming information and accesses it. Thus, lexical access of *envelope* would occur simply through contextual knowledge, without any word actually present. Certainly, this model fits with our *conscious predictions* of what we might imagine would take place if we heard a sentence fragment and were asked to guess the next likely word. Indeed, the model seems to fit generally with our clinical intuitions that patients often use context to help communicate.

Note however, that guessing is *not* what actually seems to happen in normal comprehension. In normal comprehension, sentences are heard at a very rapid rate (approximately 5–6 syllables per second). At that rate, conscious guessing cannot actually take place before the final word in the sentence is heard. Thus, while it might fit with our first-blush take on comprehension to imagine that lexical access could be driven by context in a highly interactive way, it becomes less clear that such would be the case when we consider the automatic, rapid nature of comprehension. Conscious guessing or predicting is just too slow to be a factor.

Finally, consider what would happen under this model if the sentence the listener is presented with were: "The stamp is on the desk." What would happen if the listener actually predicted that the final word should be *envelope* and accessed that word, only to find that the true word was *desk*? In this case, and perhaps many others like it, an interactionist account would predict wrongly, interfering with normal processing. Clearly, however, context does have an effect on lexical interpretation during natural comprehension. The question is, does it do so in a highly interactive/predictive manner? (See Blackwell & Bates, 1996; see also MacDonald, Pearlmutter, & Seidenberg, 1994, for a recent version of this approach called *constraint satisfaction*.)

An alternative model of lexical access holds that context effects take place only *following* access of a word and its meanings, and that lexical access during normal comprehension is entirely *form driven*. By this, we mean that once the phonological form of a word is processed, lexical access occurs. Context effects take place, not as conscious predictions, but as later processing of a word following access (the most comprehensive model of this is found in Fodor, 1983; see also Forster, 1979). This model is often called the modular access model in that access is separated in time from the interaction of other information in lexical processing. Thus, under this model, we do not predict, either consciously or unconsciously, during normal comprehension; contextual information is not viewed as placing constraints on lexical access, but rather as working on the products of lexical access.

These two major approaches to comprehension in general (and lexical processing in particular) have clear differences. The model of lexical access as a highly interactive process fits well with comprehension processing as revealed by temporally late conscious introspection (and other tasks that reflect processing offline, after it has taken place). However, it may not necessarily reflect the more automatic, unconscious processes underlying normal comprehension. The form-driven model of lexical access denies that prediction, conscious strategies, or contextual constraints work actively in normal, real-time comprehension. So, how do we differentiate these two possibilities empirically?

To determine if context effects predict or predetermine lexical access or only follow lexical access in time, it is necessary to determine the relative point at which context has an effect on processing during normal ongoing comprehension. It is only by using a particular class of online tasks that such temporally evanescent details can be determined—online tasks that do not cause the listener to bring conscious reflection or any other comprehension-extraneous mental process to bear on ongoing auditory comprehension. There are, unfortunately, only a few such tasks in the current arsenal of language researchers. One of the more sensitive of these is termed Cross-Modal Priming (CMP).

CMP tasks come in many varieties, but all involve the following conditions and properties: First, sentential or discourse material is presented auditorily to subjects, who are told that their major job is simply to understand the sentence(s) (or discourse) they hear. Subjects are tested for comprehension throughout the experiment in order to keep attention focused on the major task. Typically, this comprehension check requires the subject to either paraphrase or answer multiple choice or yes-no questions about randomly selected sentences. Second, subjects are told they have another task to perform: namely, at some point while they are listening to the sentence(s), a visual item will appear momentarily on a screen in front of them and they will have to make a decision about that visual item. In the typical version of this task, the visual item is a letter string to which subjects are required to make a lexical decision (“Word” or “Nonword”) or are required to read. The presentation time—the time the stimulus stays on the screen—is around 500 ms. Reaction times (RTs) or naming times to the visually presented stimulus are recorded (Swinney, Onifer, Prather, & Hirshkowitz, 1979).

Several details about this technique need to be mentioned: First, the auditory sentence always continues to its end—beyond presentation of the visual item. That is, the sentence is never ended with the visual probe. Hence, the probe is not integrated into the ongoing sentential material by listeners (Nicol, Swinney, Love, & Hald, 1997). Second, the secondary task never requires the subject to make metalinguistic judgments about the sentential material they hear (such as: “was this visual item actually IN the sentence?”). The task specifically prevents metalinguistic examination of the auditory sentence because the subject’s task is to respond to the visual stimulus without consciously reflecting on the sentence itself. This is critical because metalinguistic examinations necessarily involve processes beyond and in addition to those involved in normal comprehension. Third, although visual presentation of the target does interrupt presentation of the sentence to some degree (even though the sentence continues and subjects must listen to all of the sentence), at least up to the point of the visual target presentation, processing of the sentence is uninterrupted and normal. In this regard, the task differs considerably from many other online tasks (see below for a discussion of word monitoring). Thus, this task is one of the least intrusive behavioral techniques we have for the online study of the normal comprehension process.

Most important, there is a planned relation between the auditory sentence comprehension and visual target classification tasks the subject performs. The visual lexical decision or reading target is (or in the control condition, is not) associatively or semantically related to a noun or noun phrase in the sentence. It is, of course, something about this noun that we are interested in. The CMP task is based on the principle of automatic semantic priming (see, for example, Meyer, Schvaneveldt, & Ruddy, 1975; Neely, 1977), whereby the occurrence of a word (the prime) just before processing of another item (the primed item) that is associatively and/or semantically related to that item, results in speeded processing of that second item. For example, briefly presenting DOCTOR before NURSE will result in faster RTs to the decision that NURSE is a word than if an unrelated word like FACTOR is presented before NURSE. The CMP task uses the fact that priming occurs between related words (or between associatively/semantically related words and pictures) to tell us *when* a particular word (the prime) is actively being processed in a sentence.

Lexical Ambiguity

The CMP technique, for example, can tell us when the meanings of words are active in a sentence by probing at different points in the sentence. As it turns out, many words are ambiguous or have multiple meanings. Consider an example in which subjects are presented with the following spoken sentence:

> “The man saw several spiders, roaches, and other bugs [1] in the corner [2] of his room.”

Assume we were interested in determining whether the meaning of the word *bugs* was active at various points during comprehension of the sentence. We could present an associated visual probe (such as ANT) at each of the points marked by [1] and [2] and see whether RTs to decide that ANT is a word are faster than the RTs to an unrelated control word, for example, SEW. Note that probe position [1] is immediately after *bugs* has been heard, while probe position [2] is approximately 1 second after *bugs*. If RTs to ANT were faster than to its control word at either position, then we would know that the insect meaning of *bugs* must have been active.

Let us consider again the question of highly interactive vs. form-driven models of lexical processing. Here, the critical empirical question is whether listeners use context to predict or place prior constraints on the access of word meanings during normal comprehension. And it is here that the use of lexical ambiguities comes into play. It is well established in the experimental literature that in the absence of a context, all meanings of an ambiguous word are accessed when it is heard or read (Simpson & Burgess, 1985). Thus, one way to examine the time-course of context effects on lexical access would be to place ambiguous words in strongly biasing contexts such that only one meaning of the word could logically be predicted from the context.

Take the last example given above. The word *bugs* in that sentence is ambiguous (one meaning relates to insects—where ANT is a strong associate—and another meaning relates to listening or spying devices—where SPY is a strong associate). Under the highly interactive model of lexical processing, if the context found in that sentence ("…several spiders, roaches, and other…") is sufficiently strong to predict or at least constrain lexical access of the meanings of the word *bugs*, one would predict that only the contextually relevant meaning of *bugs* (ANT) should be accessed (and hence primed) when the word is heard (at position [1] in the sentence); the contextually irrelevant meaning of the word (SPY) should not be activated at all under this model. On the other hand, the form-driven model would predict that both meanings of the ambiguity should be immediately accessed independent of contextual bias. However, it would also predict that shortly after access, context should act to constrain *bugs* to just one, contextually relevant, meaning of the ambiguity (at point [2] in the sentence, for example). Thus, this CMP technique can be used to tease apart temporally fleeting events that make important theoretical and practical differences in our understanding of language processing.

This study has been run many times and in several languages. The results have overwhelmingly established that lexical access during normal comprehension is form driven. The data consistently demonstrate priming for lexical decisions made to visual probes that are semantically related to *both* meanings of the ambiguous word immediately after hearing the word (at probe [1])—but priming for only probes related to the contextually relevant meaning of the ambiguous word about one-half to one second later during processing (at probe [2]). Thus, context effects are seen to take place only following lexical access, and not before lexical access (see, among others, Ahrens, in press; Onifer & Swinney, 1981; Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982; Swinney, 1979). Even with very stringent controls that carefully manipulate strength of context (see, for example, Tabossi, 1988, for issues on context strength), form-driven access is supported (Love & Swinney, 1996). Thus, lexical access *during normal comprehension* appears not to be driven by prediction or guessing of upcoming words, but is based on what is actually heard of the word.

We emphasize the words "during normal comprehension" in the previous sentence because there are any number of experimental techniques that claim to demonstrate context effects acting predictively on lexical access. However, all of these claims involve the use of tasks, methods, and procedures that bring conscious prediction (guessing, at some level) into the process of comprehension. Many of these are considered by their users to be online, as they do examine processes before the sentence is over. Thus, a task simply being online (as opposed to offline) is not sufficient on its own to guarantee sensitive, subtle, and uncontaminated examination of ongoing language processes. The relevant task must both be online and must not involve cognitive processes that are outside of normal comprehension. Clearly, it is difficult to find experimental techniques that have both of these characteristics.

Not All Online Tasks Are the Same: Word Monitoring

Another putatively online task has produced a very different type of result than the form-driven pattern described above. Consider the following experiment reported by Marslen-Wilson, Brown, and Tyler (1988). They used a *word monitoring* task whereby sentences are presented in the auditory modality. Before the onset of each sentence, a word is presented momentarily and the subject is required to press a button as soon as she hears the word in the sentence; monitoring times for the word are recorded. For example, consider the following sentences, which have been manipulated for the fit between the verb and the post-verb noun phrase:

1. They pass the beach on the way to the hospital.	Plausible
2. They measure the beach on the way to the hospital.	Pragmatic anomaly
3. They chew the beach on the way to the hospital.	Semantic anomaly
4. They yawn the beach on the way to the hospital.	Syntactic violation

In (1) the context is plausible; that is, it is quite likely in the real world that someone could pass a beach on the way to a hospital. In (2), however, though it is possible to measure a beach on the way to a hospital, it is quite unlikely and hence the context is pragmatically weird. In (3), though the verb *chew* allows a direct object NP, the semantics of the verb requires that the NP be something that can be chewable and, of course, a beach isn't. And finally, in (4) the verb yawn is intransitive—it does not allow a direct object NP; hence, the sentence is ungrammatical. Results indicated that subjects evinced a continuum of monitoring times (in this case, for *beach*); they were fastest in the plausible context and slowest when confronted with a syntactic violation, with pragmatic and semantic anomalies somewhere in between.

At first glance, this pattern suggests that listeners immediately use semantic, pragmatic, and syntactic information to help understand sentences; monitoring times increased for each type of violation because, the reasoning goes, listeners were immediately sensitive to this information. It thus appears that Marslen-Wilson et al. (1988) have secured strong evidence in favor of an interactive account of language processing. However, recall our previous discussion where we suggested that an online task, per se, is not sufficient to guarantee uncontaminated examination of ongoing language processes. We believe this task is inherently incapable of tapping into the initial effects of ongoing processing because it requires the listener to consciously reflect on every word in the sentence. This conscious reflection allows all sorts of available information to interact with the monitoring decision.

To see what we mean here, put yourself in the subject's shoes for a moment. You are given a word (*beach*) and you are told that sometimes you may hear that word in the subsequent sentence, and, if you do, hit the response button as fast as you can. How will you accomplish this task? You are going to attempt to match the to-be-monitored word to *each and every word that you hear*. That is, you are making a decision at each word in the sentence (most of the time "NO," one might be "YES"), consciously reflecting on whether that word that you just heard is indeed the word that you are required to find. Consider also the memory requirements of the task: At each word in the sentence you are attempting to recall the word to be monitored and perhaps even rehearsing it. Word monitoring, therefore, is a task that is quite unlikely to be sensitive to the more subtle, automatic aspects of sentence processing.

Our interpretation is buttressed by an experiment reported in Lewis (1996) (see also Borsky & Shapiro, in press). Consider:

Plausible:	Ken fed [1] the litter [2] every morning	CONTROL: WITCH
Implausible:	Ken baked [1] the litter [2] every morning	RELATED: TRASH
Nonsyntactic:	Ken yawned [1] the litter [2] every morning	

We used the CMP task and presented probes either before the post-verb NP [1] or immediately after it [2]. Note the similarities of these examples to those used in the Marslen-Wilson et al. (1988) study. The plausible sentence type consisted of a verb, *fed*, which has semantic and syntactic properties that allow a direct object like *the litter*. The implausible sentence type used a verb, *baked*, which has semantic-pragmatic properties incongruent with a direct object like *the litter* (that is, people typically don't bake litter!). Finally, the nonsyntactic sentence type used an intransitive verb like *yawn* that did not allow a direct object NP of any kind. Importantly, we used probes (e.g., TRASH) that were related to the sense of the word (*litter*) that was *not* reflected in the sentence. For example, in the plausible sentence example above, the context-appropriate sense of the direct object NP would be something related to a litter of puppies or cats, and not garbage.

The pattern of results we focus on here is that RTs to the related probe when presented immediately after *litter* (i.e., at point [2]) were significantly faster than RTs to the unrelated control probes in all sentence contexts. That is, listeners accessed a meaning of *litter* (*trash*) that was incompatible with the sense suggested by the context. Also, no differences in the related or control probes were observed when comparing across sentence contexts.

These patterns suggest that sentence context does not immediately influence lexical access; that is, access appears to be form driven, unlike that found in the Marslen-Wilson et al. (1988) study. Again, we attribute the different results in the two studies to task distinctions: CMP is particularly sensitive to automatic, fast-acting effects (and, it turns out, to later-occurring effects as well, depending on where the probes are placed); word monitoring involves more cognitive participation and is thus insensitive to such effects. Putting it another way, we believe that Marslen-Wilson et al. couldn't help but find what they found; the task they used guaranteed it by requiring subjects to consciously compare each word in the sentence to the to-be-monitored word.

The moral of the story is that not all online tasks are created equal. The clinical implications of this fact, we feel, are pretty clear: If online tasks are to be used to inform us about underlying language processes (and hence are to be used to let us know about underlying deficits in disordered processing), we need to make sure that they are measuring what they claim to be measuring.

Accessing the Features of Categories

Within the lexical processing domain, the CMP task is not only useful for investigating lexical ambiguities. We have recently used this technique to investigate the online organization of categorical information (Raczaszek, Shapiro, Tuller, & Kelso, 1998). With this study, we have shed further light on the time-course of sentence processing. According to prototype theory (Rosch, 1975), objects in the world come in natural groupings; a typical member of a category is one that has many features in common with other members of that category and few features in common with nonmembers of the category. For example, if we asked 100 subjects to rank order different kinds of BIRDS along a typicality continuum, the results would very likely indicate that ROBIN would be ranked as more typical than EAGLE, which in turn would be ranked as more typical than OSTRICH. This continuum is generated because subjects somehow know that the properties of ROBIN are shared by more members of the category *birds* than the properties of, for example, OSTRICH. Indeed, evidence shows that typical exemplars are generated more easily, faster, and so on, than atypical exemplars (Rips, Shoben, & Smith, 1973; Rosch, 1973; see also Smith & Medin, 1981).

One question we asked was whether we would observe this typicality effect online that we often observe in offline tasks. Why is this question important? One reason is that some brain-damaged patients do not show normal categorization for real-world objects (see, for example, McCleary, 1988; McCleary & Hirst, 1986). There is also some indication that, unlike normal subjects, fluent patients with aphasia do not abstract a prototype from a set of exemplars

(Wayland & Taplin, 1985). This evidence almost always comes from offline tasks where subjects are asked to rank or rate exemplars of categories or are asked to "put the objects that go together into one pile." However, given that subjects have to do much more in these tasks than simply show their knowledge of categories (e.g., they have to visually examine the objects or pictures of objects, decide one by one which object goes with which object, remember the task instructions, etc.), it is possible that knowledge of categories is not the focus of the observed deficit.

Another question we addressed was when, during the temporal unfolding of the sentence, would context have an effect on the access of category information? This question is important because of the two accounts of lexical processing we reviewed previously. Recall that the highly interactive account claims a relatively privileged role for context; context should dictate which exemplar is typical or atypical. And context does seem to matter: In offline judgment tasks, the structure of categories appears to be flexible. Thinking about a category in the context of a particular point of view can invert its typicality structure. For example, *ostrich* can be a more typical bird than *robin* in the context of an African point of view (Barsalou, 1983). Proponents of the interactive account often use such (offline) facts in their arsenal of argumentation. On the other hand, if we extend the form-driven account to encompass category information, we would predict that though context indeed matters, it should not matter initially.

We assessed the typicality effect online by using a variant of the CMP task. We compared response times for probes related to typical versus atypical exemplars in different contexts. Consider the following examples:

Neutral Context:

The food was eaten by the *bird* even though it was not fresh.

Atypical Biased Context:

The mouse was eaten by the *bird* even though it tried to hide.

In the neutral context condition, the sentence was equally biased toward either the typical (e.g., ROBIN) or atypical member (e.g., EAGLE) of the category (based on offline judgments); in the atypical biased context condition, the sentence was biased toward the atypical member (EAGLE) (again, based on offline judgments). The subject's task was to attend to the spoken sentence and to make a cross-modal lexical decision on the visually presented probe. Response times for the two probe types (ROBIN, EAGLE) were compared at three probe positions: 0 ms (at the offset of the category name; e.g., *bird*), and 450 ms and 750 ms past the category name.

The pattern of results indicated that RTs were significantly faster for the typical exemplar (e.g., ROBIN) than for the atypical exemplar (e.g., EAGLE) at the offset of the category name in both the neutral and atypical biased contexts. At 450 ms past the category name, however, context effects were observed whereby RTs for EAGLE decreased significantly in the atypical biased contexts—the context biased toward EAGLE. An additional experiment pinpointed that context affects sentence processing somewhere between 350 to 450 ms past the point where it could, in principle, have an effect. The implication for sentence processing is clear: Once again, context does not have an *immediate and initial* influence on lexical activation (in this case, the activation of category information); it is only after the fact that context exerts its influence.

Argument Structure Access

We have also investigated lexical processing by focusing on a type of information—argument structure—that has played an important role in linguistic theory. Part of what is represented with verbs in a language user's lexicon or mental dictionary is *argument structure*. Arguments are roughly the "participants" associated with the action described by a verb. In syntactic terms, an argument is often a noun phrase (NP). For example, the verb *kiss* requires both a *kisser* and a *kissee*, as in "The girl kissed the boy," where the subject NP (*the girl*) and the direct object NP (*the boy*) serve as NP arguments of the verb. Thus, *kiss* is said to have a two-place argument structure (i.e., it requires two arguments).

Verbs can differ as to the number of arguments each allows and even the number of argument structures each allows. For example, though the transitive verb *kiss* allows a single, two-place argument structure, an intransitive verb like *sleep* allows a single argument structure containing one subject argument (e.g., *Joelle*), as in "Joelle slept easily." Still other verbs, like *send*, allow either a two-place or a three-place argument structure, depending on whether or not the third argument is observed in the sentence, as in "Joelle sent the letter" and "Joelle sent the letter to her friend," respectively.

In our experiments (see, for example, Shapiro, Brookins, Gordon, & Nagel, 1991; Shapiro, Zurif, & Grimshaw, 1987, 1989; see also Rubin, Newhoff, Peach, & Shapiro, 1996), we were interested in whether normal listeners activate the argument structure properties of verbs when the verb is initially encountered in a sentence. One reason why this issue is important is because argument structure is a type of lexical property that has obvious syntactic repercussions. As we have shown, a verb that allows two arguments generally requires the syntax of the sentence containing that verb to accommodate two NPs. Thus, accessing a verb's argument structures could go far in determining the syntax of the sentence in which the verb is contained. Clinically, this means that when we design assessments or intervention that target sentence-level material, we need to carefully consider the interaction of lexical properties with syntax. We will consider this point again at the end of our paper.

Back to our experiments: Because we were interested in what occurs locally in the sentence rather than what occurs after a subject has interpreted the entire sentence, we used a variant of cross-modal priming, the cross-modal interference (CMI) task. Unlike CMP, CMI uses the presentation of lexical probes that are always unrelated to the items in the sentence; thus, no priming occurs. The idea here is that as processing the sentence at a particular point becomes more difficult to do, lexical decision times on probes presented locally will increase. As an example, in one experiment we constructed our sentences so that they contained verbs that accommodated either one or two argument structures. We presented our lexical decision probes in the immediate vicinity of the verb. For example, consider:

Mitzi fixed [1] the car yesterday afternoon.

Mitzi sent [1] the car yesterday afternoon.

Fix (like *kiss*) is a verb that requires two arguments embedded in a single argument structure, whereas *send* is a verb that can allow two possible argument structures, one with two arguments as in the sentence above, "Mitzi sent the car…," or one with three arguments, as in "Mitzi sent the car to the garage…." Thus, we claimed that *send* was representationally more complex than *fix* because it allowed more argument structures. We assumed that as the verb became more complex, it would take longer to make the lexical decision on the unrelated probe, perhaps because it would take more processing resources to activate a verb with more argument structures relative to a verb with less, increasing RTs to the lexical decision. And, indeed, that is what we observed. Verbs that required more argument structures (e.g., *sent*) resulted in longer RTs on the CMI task than verbs that required fewer structures (e.g., *fixed*).

These patterns suggest that when a listener encounters a verb in a sentence, she activates all possible argument structures for the verb (that's why a verb that allows two structures yields longer RTs than a verb that allows just one). In subsequent experiments we found that even when we biased the sentence toward one particular argument structure, still all argument structures remained momentarily active at the verb. These results show similarities to the ambiguity work we discussed earlier, i.e., form-driven lexical access. However, as you shall soon see, these two activities—activating multiple senses for a word and activating multiple argument structures—can be dissociated in brain damage.

Aphasia and Lexical Processing

We now turn to some work we have done that has investigated lexical processing after brain damage (Prather, Shapiro, Zurif, & Swinney, 1991; Swinney, Zurif, & Nicol, 1989). Because there have been reports that some patients with aphasia have difficulty naming objects (or pictures of objects) yet show knowledge of the concepts to which the names refer, we conducted online investigations of lexical processing to zero in on the lexical deficit; that is, we have been interested in charting the time-course of the deficit. Recall that normal listeners appear to activate multiple senses of an ambiguous noun, even in contexts that are biased toward only one of the senses. Thus, lexical access is said to be *form driven.* We found that though lexical processing after brain damage respects the modularity of the system, patients with Broca's aphasia did not appear to activate multiple senses of ambiguous nouns at the right temporal point, that is, at the point where the noun was encountered in the sentence. Instead, these patients showed normal activation patterns downstream from the ambiguity. Remember the *bugs* experiment? Our patients with Broca's aphasia activated only the most frequent meaning at the offset of the word *bugs* (e.g., they showed priming only for ANT, and not for SPY). Yet at a later probe point these patients indeed showed activation for both meanings. Thus, we surmised that the brain damage underlying Broca's aphasia results in a slower-than-normal time-course of lexical activation, disallowing the activation of information at the right time in the processing stream. Interestingly, patients with Wernicke's aphasia showed normal activation patterns; that is, like normal subjects, they activated multiple senses for ambiguous nouns right when the ambiguous noun was encountered.

We also extended the argument structure work to investigations of aphasia. Patients with Broca's aphasia have been shown to exhibit more difficulty with naming and producing verbs relative to nouns (Saffron, Schwartz, & Marin, 1980; LaPointe, 1985; Miceli, Silveri, Mocentini, & Caramazza, 1986). Most importantly, as we have explained above, they did not show normal online lexical access when confronted with ambiguous nouns as did patients with Wernicke's aphasia. Furthermore, some patients with Broca's aphasia have difficulty understanding sentences whose NP-arguments are not in canonical positions (see, for example, Caplan & Futter, 1986; Grodzinsky, 1990, 1995). In English, Subject-Verb-Object is considered canonical word order (e.g., "The girl kissed the boy"). So sentences like passives ("The boy was kissed by the girl"), object clefts ("It was the girl who the boy kissed"), and wh-questions ("Which boy did the girl kiss?") have direct object NPs that occur before, rather than after, the verb. Understanding these are particularly problematic for some patients with Broca's aphasia.

Thus, given the role of argument structure in sentence understanding, and given the disrupted lexical access routines exhibited by patients with Broca's aphasia, we predicted that these patients would show a similar disruption in the lexical activation of argument structures. In other words, we predicted that these patients would not show access for multiple argument structures of verbs, at least not at the point where the verb was encountered in the sentence. On the other hand, we predicted that our patients with Wernicke's aphasia would show normal sensitivity to these lexical properties since they also show the normal access pattern with lexical ambiguities (that is, they access multiple senses of an ambiguous noun).

However, we found just the opposite. Patients with Broca's aphasia evinced normal activation of a verb's argument structures, yet patients with Wernicke's aphasia appeared to be insensitive to such lexical information (Shapiro & Levine, 1990). Furthermore, even in complex sentences that they ultimately failed to understand (as measured by offline sentence-picture matching tasks, for example), patients with Broca's aphasia showed normal online activation of a verb's argument structures (Shapiro, Gordon, Hack, & Killackey, 1993).

Apparently, then, the knowledge and access of a verb's argument structures cannot explain the difficulty patients with Broca's aphasia have in understanding structurally complex sentences. Below, we consider another explanation for this difficulty, and we discover facts about the relation between lexical and structural processing that we could not have detected without the use of online measures. Our explanation will also encompass the behavior of our patients with Wernicke's aphasia, but for now note that argument structure contains a bit of semantics. That is, arguments are not solely structural notions but also involve concepts such as Agent of Action (in English, typically the subject NP) and Patient of Action (typically the object NP). We surmised that patients with Wernicke's aphasia do not show online sensitivity to argument structure because they have a more general problem with semantic properties.

Structural Processing

Consider the following wh-question construction in English:

> Which boy did the crowd at the party accuse of the crime?

In this, the direct object of the verb *accuse* is the noun phrase (NP) *which boy*. However, contrary to canonical order in English, the direct object precedes the verb, rather than following it. Thus, for the above example, the underlying canonical order of participants in the sentence is presumed to be:

> *The crowd*$_{\text{(subject)}}$ at the party (did) *accuse*$_{\text{(verb)}}$ *which boy*$_{\text{(object)}}$ of the crime?

Syntactic theories provide various formal accounts describing the basis for such deviations from canonical order. The best known account for the surface form of wh-constructions (constructions involving the use of relative pronouns *who*, *what*, *which*, and *that*, as found in wh-questions and in relative clauses) involves movement of the direct object from its underlying canonical position (following the verb) to the fronted surface position occurring before the verb (Chomsky, 1981, 1995; see also Shapiro, 1997, for a tutorial on syntactic theory). Following convention, we refer to the position following the verb from which the direct object was moved as the *gap*. Thus, the gap is the now-empty position following the verb that was created by the movement of the object to a fronted position. In contrast, the moved direct object is referred to as the filler.

A long-standing and fundamental question for models of language processing is how the comprehension device links the moved constituent—or filler—to the gap to allow for interpretation. Note that a listener/reader must indeed connect the two positions to understand the sentence. One aspect of this question asks if gaps are filled online; that is, is the filler (moved NP) inserted into the gap when the gap is immediately encountered?

Consider, for example, the following object-relative sentence:

> The policeman saw the boy $_i$ who $_i$ the crowd at the party [1] accused $_i$ [2] of the crime.

In this sentence, the direct object of the verb *accused* is the NP, *the boy*, which has been displaced from its post-verb position to a position occurring well before the verb (the object NP, the relativizer *who*, and the gap have all been marked here with the same index ($_i$) to indicate that they all co-refer.)

The CMP technique has been successfully used to determine whether listeners fill gaps online. Swinney, Ford, Frauenfelder, and Bresnan, (1988; also reported in Nicol & Swinney, 1989) presented subjects with spoken sentences such as that above. At the positions marked by [1] and [2], visual probes that were semantically related to the correct antecedent (*boy*), as well as unrelated control probes, were presented. As always with this task, subjects were required to make lexical decisions to the visual probes. It was discovered that there was significant priming for probes related to the correct antecedent at the gap ([2]), but not at the pre-gap ([1]) probe site. That is, RTs to probes related to *the boy* were faster than RTs to an unrelated control probe, but only at the gap position. This pattern indicates that at probe point [1] the word *boy* was no longer actively being processed by the comprehension device. However, just one word later in the sentence—at the point of the structural gap following the verb—the word *boy* is suddenly reactivated (hence causing priming to a related word probe at that point). Importantly, probes related to other NPs in the sentence, those that were not the filler for the gap (e.g., *crowd*, *policeman*), were not found to be accessed at the gap. This result demonstrated that only the *structurally appropriate antecedent* was activated (see also Love & Swinney, 1996).

Additional gap-filling experiments were conducted to investigate whether reactivating the antecedent to the gap could be constrained by extrasyntactic information, as would be predicted by an interactive account (e.g., Swinney & Osterhout, 1991). Consider:

> The police captain said that the cop from his precinct that the soup [1] in the bowl had eaten [2] was going to give a talk on public policy.

Note here that the direct object of *eaten* is the moved NP—*the cop from his precinct*. Regardless of the real-world impossibility of a bowl of soup eating a cop, a reactivation effect for the displaced direct object (e.g., *cop*) was observed. That is, only at probe position [2]—the gap position—was there priming for a related probe. Results like these suggest that gap-filling is a reflexive, automatic process that works in isolation from contextual and probabilistic information; it's modular. We emphasize here that these details of structural processing are only obtainable via sensitive online techniques that reflect subtle aspects of language processing without involving conscious reflection.

Gap-Filling in Aphasia

An important question concerns how aphasic individuals with damage to neurological tissue that has been posited to underlie aspects of structural processing will process these object-relative constructions. Patients with agrammatic Broca's aphasia have demonstrated significant difficulty in understanding object relative (and related) constructions. In fact, they typically perform at chance on offline measures (sentence-picture matching) on such sentences (see Grodzinsky, 1995, for a linguistic description of their performance). The question, then, is precisely where in the complex processing of a sentence are these patients with aphasia failing? It might be that these patients simply never try to link verbs with their arguments (their direct objects)—i.e., this may be a structural/syntactic processing problem. Or, alternatively, it may be that some other aspect of language processing is disrupted in these patients that percolates through the system to disrupt the understanding of object relative constructions. Clearly, knowing which is the case should have clinical implications.

A series of studies (e.g., Swinney, Zurif, Prather, & Love, 1996; Zurif & Swinney, 1994) have used CMP with agrammatic Broca's aphasics to examine if and when fillers are activated in object-relative sentences. They discovered that these patients do not reactivate the appropriate antecedent (filler) at the gap site while comprehending these object-relative sentences. Recall that in the lexical processing studies, patients with Broca's aphasia did not show immediate, exhaustive access of the multiple senses of ambiguous nouns, suggesting that lexical access operates in a slower-than-normal manner for these patients. Hence, it seems that the difficulty these patients have with object relative constructions is not a function of a disruption to syntactic knowledge or syntactic processing, per se, but may be a result of a difficulty in activating and reactivating lexical information rapidly enough during ongoing processing to find the correct direct object for a verb in real time. Once the gap position has passed by in the temporal unfolding of the sentence—and these patients do not activate the filler—it may be too late to repair the damage.

To review—and combining our work on the activation of argument structures and gap-filling by patients with aphasia—we have found that patients with Broca's aphasia, but not patients with Wernicke's aphasia, normally access the argument structure properties of verbs, even in complex sentences that they ultimately fail to understand (Shapiro et al., 1993). Furthermore, these complex sentences included object relatives of the sort investigated in the gap-filling studies. Yet patients with Wernicke's aphasia, but not patients with Broca's aphasia, show normal online gap-filling (see also Zurif, Swinney, Prather, Solomon, & Bushell, 1993). Thus, the lexical process of accessing a verb's argument structures and the syntactic process of filling a gap appear to be independent and may depend on distinct neurological resources.

Clinical Relevance

Now that we have spent some time trying to convince the reader that online examinations of language processing have borne considerable empirical fruit, we turn to some additional comments on the clinical implications of this work. There are, of course, various ways to evaluate research in regard to its clinical utility. For example, it seems to us that knowing something about the operation of the normal language processing system is crucially important to understanding a language deficit and, ultimately, to understanding how to go about circumventing that deficit. Also, it is clinically useful simply to detail a language deficit in terms of a patient's strengths and weaknesses. For example, if a patient shows priming for an ambiguous word, then that subject has knowledge of the properties of that word, and lexical access is intact. If a patient shows an argument structure complexity effect, then knowledge of argument structure is likely intact. If a patient shows the typicality effect, then it is likely that the subject knows quite a bit about the structure of basic categories. If a patient fills a gap online, then that syntactic reflex is behaving normally. These are all important things to know.

If any of these factors are amiss, or if there is a discrepancy between what is found online and what is found offline, then we have also learned some clinically useful facts. For example, consider once again the typicality effect. Recall that there is some evidence that brain damage alters a patient's ability to categorize objects into natural classes, as determined by offline measures. We are currently designing a set of experiments that will assess whether patients who show such offline categorization deficits also show similar deficits online. Our initial predictions are that some of them will, indeed, show normal or near-normal online performance. What would such a pattern mean? Going back to our introductory comments, it would likely mean that the mental representations computed by these patients are intact, and so too is the initial operation that activates them. However, somewhere between activating categories and making use of them in offline metalinguistic tasks, the process breaks down. Perhaps the cognitive demands (i.e., memory, attention, problem solving) of the offline task is part of the observed deficit. Of course, this is an empirical question yet to be fully addressed. Importantly, however, it can only be addressed by comparing online to offline performance.

Luckily, we have more concrete examples of clinical utility than this last promissory note would indicate. Patients with Wernicke's aphasia appear to have difficulty with initially activating the argument structures of verbs. Thus, focusing on the lexical properties of verbs would be a useful clinical tactic for these patients. Patients with Broca's aphasia evince strength in this area, yet do not show normal online (or even offline) comprehension of sentences that require filling gaps. And, it turns out, their sentence production of complex sentences also suffers. Thompson and colleagues (e.g., Thompson & Shapiro, 1995; Thompson, Shapiro, et al., 1997) have, over the last several years, exploited the role of argument structure in syntax and the apparent strength of patients with Broca's aphasia regarding the knowledge and access of this information. We have devised a successful treatment program that trains these patients to produce complex sentences (e.g., wh-questions that have obvious everyday utility) while manipulating the argument-taking properties of verbs. The treatment program, then, is based on the strengths and weaknesses of patients with Broca's aphasia observed from a combination of online and offline tasks.

This last example of direct clinical application more generally suggests that controlling for lexical and structural properties of language materials used in the clinic would surely be a useful thing to do. Consider here a brief example of how a clinician might go about this task. Verbs can be classified in terms of the number and type of arguments each accommodates and whether the arguments are obligatory or optional (for details, see, for example, Shapiro et al., 1987, 1991). If we were interested in expanding the sentence repertoire of a patient with a language disorder (in terms of either production or comprehension), we might begin with those verbs that allow either one or two obligatory arguments, placing them into simple sentence structures (e.g., "The baby slept quietly," "The boy hit the ball"). Those simple verbs (and their NP arguments) could also be organized by frequency given that most sentence processing accounts claim a relatively privileged role for such information (e.g., MacDonald et al., 1994). We could then expand the set to include verbs that are optionally transitive; that is, those that can either take one argument or two (e.g., "the baby ate" and "the baby ate the carrots"). Continuing, the materials could be expanded even further, requiring the production or comprehension of sentences containing verbs that obligatorily require three arguments, as in "The girl put the coat in the closet," and sentences containing verbs that select for an optional third argument, such as "The woman sent the letter" and "The woman sent the letter to her friend." Sentences containing complex verbs that take sentential arguments could be targeted, such as "The boy discovered that the car was missing." And, ultimately, noncanonical sentences that contain fillers and gaps—for example, passives—could be used, while still controlling for the argument-taking properties of the verbs (e.g., "*The hamburger* was eaten ___ by the boy yesterday?).

Though we have suggested here a continuum from least to most complex—as is the conventional wisdom in assessment and intervention—Thompson and colleagues (Thompson, Ballard, & Shapiro, 1997) have found that beginning sentence production treatment with more complex structures may be more facilitating than beginning with simple structures (because simpler structures are often embedded in more complex ones; basically, you get "two for the price of one"). Note that the approach of controlling for such lexical and syntactic properties is well-grounded empirically since there is considerable online evidence that verb-argument structures, frequency of occurrence, gap-filling, and the like, affect sentence processing in both normal and brain-damaged populations.

Summary and Final Thoughts

In this paper we have attempted to give readers an idea of some of the past and current online work we have been associated with that has shed some light on the complex process of comprehending sentences in normal and brain-damaged subjects. To sum up, the typical tasks and tests clinicians use to assess and train patients with language disorders are offline, necessarily allowing the output of multiple processes to impinge on a response. These responses, therefore, are "contaminated" by the patients' strengths and weaknesses in areas as disparate as visual, auditory, and motor processing, memory, attention, problem solving, and decision making, not to mention language-specific areas. It is crucial, therefore, that clinicians understand what their patients bring to the table.

Are we suggesting that clinicians use online tasks in their everyday work? Though we surely can't dismiss this possibility in the future, we are not suggesting it presently simply because at the very least using such techniques takes time and expense, things that are in relatively short supply. What we are suggesting is that clinicians be aware of the literature regarding online processing—that such a literature might very well have an impact on the goals of assessment and treatment. A final, personal note: The first two authors of this paper were trained initially as speech-language pathologists. Part of the motivation for our work has been about the patients—attempting to understand what is going on in their brains when they can't tell us. Online tasks have allowed us to get a peek at the inner-workings of our patients' (and normal subjects') minds; this, by itself, has been worth the effort.

Author Note

Much of the work reported in this manuscript was supported by NIH grants DC00494 and DC01948. We thank the following colleagues for allowing us to present their work: Edgar Zurif, Penny Prather, Tracy Love, Joanna Raczaszek, James Lewis, Cynthia Thompson. And, of course, we thank our patients for their continuing efforts in helping us to investigate brain-language relations.

References

Ahrens, K. (in press). Lexical ambiguity resolution: Languages, tasks and timing. In D. Hillert (Ed.) *Sentence processing: A cross-linguistic perspective*. San Diego, CA: Academic Press.

Barsalou, L. W. (1983). Ad-hoc categories. *Memory and Cognition*, *11*, 211–227.

Blackwell, A., & Bates, E. (1996). Inducing agrammatic profiles in normals: Evidence for the selective vulnerability of morphology under cognitive resource limitation. *Journal of Cognitive Neuroscience*, *7*, 228–257.

Borsky, S., & Shapiro, L. P. (in press). Context effects revisited. In D. Hillert (Ed.), *Sentence processing: A cross-linguistic perspective*. San Diego, CA: Academic Press.

Caplan, D., & Futter, C. (1986). Assignment of thematic roles by an agrammatic aphasic patient. *Brain and Language*, *27*, 117–135.

Chomsky, N. (1981). *Lectures on government and binding: The Pisa lectures*. Dordrecht: Foris.

Chomsky, N. (1995). *The minimalist program*. Cambridge, MA: MIT Press.

Fodor, J. A. (1983). *Modularity of mind*. Cambridge, MA: MIT Press.

Forster, K. I. (1979). Levels of processing and the structure of the language processor. In W. E. Cooper & E. C. T. Walker

(Eds.), *Sentence processing.* Hillsdale, NJ: Erlbaum.
Grodzinsky, Y. (1990). *Theoretical perspectives on language deficits.* Cambridge, MA: MIT Press.
Grodzinsky, Y. (1995). Trace deletion, theta-roles, and cognitive strategies. *Brain and Language*, *51*, 469–497.
LaPointe, S. G. (1985). A theory of verb form use in the speech of agrammatic aphasics. *Brain and Language*, *24*, 100–155.
Lewis, J. R. (1996). *Local contextual impenetrability of lexical access and gap-filling: A comparison of outcomes from cross-modal priming and word-by-word reading tasks.* Unpublished doctoral dissertation, Department of Psychology, Florida Atlantic University, Boca Raton.
Love, T., & Swinney, D. (1996). Coreference processing and levels of analysis in object-relative constructions: Demonstration of antecedent reactivation with the cross-modal priming paradigm. *Journal of Psycholinguistic Research*, *25*, 5–24.
MacDonald, M., Pearlmutter, N., & Seidenberg, M. (1994). The lexical nature of syntactic ambiguity resolution. *Psychological Review*, *101*, 676–703.
Marslen-Wilson, W., Brown, C. M., & Tyler, L. K. (1988). Lexical representations in spoken language comprehension. *Language and Cognitive Processes*, *3*, 1–16.
McCleary, C. (1988). The semantic organization and classification of fourteen words by aphasic patients. *Brain and Language*, *34*, 183–202.
McCleary, C., & Hirst, W. (1986). Semantic classification in aphasia: A study of basic, superordinate, and function relations. *Brain and Language*, *27*, 199–209.
Meyer, D., Schvaneveldt, R., & Ruddy, M. (1975). Loci of contextual effects on visual word recognition. In P. Rabbit & S. Dornic (Eds.), *Attention and performance, Vol. 5.* New York: Academic Press.
Miceli, G., Silveri, C., Mocentini, U., & Caramazza, A. (1986). Patterns of dissociation in comprehension and production of nouns and verbs. *Reports of the Cognitive Neuropsychology Laboratory*, *18*, Johns Hopkins University, Baltimore, MD.
Neely, J. (1977) Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited-capacity attention. *Journal of Experimental Psychology: General*, *106*, 226–254.
Nicol, J., & Swinney, D. (1989). The role of structure in coreference assignment during sentence comprehension. *Journal of Psycholinguistics Research: Special Issue on Sentence Processing*, *18*, 5–24.
Nicol, J., Swinney, D., Love, T., & Hald, L. (1997). Examination of sentence processing with continuous vs. interrupted presentation paradigms. Center for Human Information Processing Technical Report, #97-2. (University of California, San Diego).
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.
Prather, P., Shapiro, L. P., Zurif, E. B., & Swinney, D. (1991). Real-time examination of lexical processing in aphasia. *Journal of Psycholinguistic Research*, *23*, 271–281.
Raczaszek, J., Shapiro, L. P., Tuller, B., & Kelso, S. *Concepts in context: The time-course of adaptation.* Manuscript submitted for publication.
Rips, L., Shoben, E., & Smith, E. (1973). Semantic distance of the verification of semantic relations. *Journal of Verbal Learning and Verbal Behavior*, *12*, 1–20.
Rosch, E. (1973). On the internal structure of perceptual and semantic categories. In T. M. Moore (Ed.), *Cognitive development and the acquisition of language.* New York: Academic Press.
Rosch, E. (1975). Cognitive representations of semantic categories. *Journal of Experimental Psychology: General*, *103*, 192–223.
Rubin, S. S., Newhoff, M., Peach, R. K., & Shapiro, L. P. (1996). Electrophysiological indices of lexical processing: The effects of verb complexity and age. *Journal of Speech and Hearing Research*, *39*, 1071–1080.
Saffron, E. M., Schwartz, M. F., & Marin, O. S. M. (1980). Evidence from aphasia: Isolating the components of a production model. In B. Butterworth (Ed.), *Language production 1.* New York: Academic Press.
Seidenberg, M., Tanenhaus, M., Leiman, J., & Bienkowski, M. (1982). Automatic access of the meanings of ambiguous words in context: Some limitations of knowledge-based processing. *Cognitive Psychology*, *14*, 489–537.
Shapiro, L. P. (1997). An introduction to syntax. *Journal of Speech, Language, and Hearing Research*, *40*, 254–272.
Shapiro, L. P., Brookins, B., Gordon, B., & Nagel, N. (1991). Verb effects during sentence processing. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *17*, 983–996.
Shapiro, L. P., Gordon, B., Hack, N., & Killackey, J. (1993). Verb-argument structure processing in complex sentences in Broca's and Wernicke's aphasia. *Brain and Language*, *45*, 423–447.
Shapiro, L. P., & Levine, B. A. (1990). Verb processing during sentence comprehension in aphasia. *Brain and Language*, *38*, 21–47.
Shapiro, L. P., Zurif, E., & Grimshaw, J. (1987). Sentence processing and the mental representation of verbs. *Cognition*, *27*, 219–246.
Shapiro, L. P., Zurif, E., & Grimshaw, J. (1989). Verb representation and sentence processing: Contextual impenetrability. *Journal of Psycholinguistic Research*, *18*, 223–243.
Simpson, G., & Burgess, C. (1985). Activation and selection processes in the recognition of ambiguous words. *Journal of Experimental Psychology: Human Perception and Performance*, *11*, 28–39.
Smith, E., & Medin, D. (1981). *Category and concepts.* Cambridge, MA: Harvard University Press.
Swinney, D. (1979). Lexical access during sentence comprehension: (Re)consideration of context effects. *Journal of Verbal Learning and Verbal Behavior*, *18*, 645–659.
Swinney, D., Ford, M., Frauenfelder, U., & Bresnan, J. (1988). *On the temporal course of gap-filling and antecedent assignment during sentence comprehension.* Paper presented at the Psychonomic Society, Seattle, WA.
Swinney, D. A., Onifer, W., Prather, P., & Hirshkowitz, M. (1979). Semantic facilitation across sensory modalities in the processing of individual words and sentences. *Memory and Cognition*, *7*, 159–165.
Swinney, D., & Osterhout, L. (1991). Inference generation during language comprehension. In A. Graesser & G. H. Bower (Eds.), *The psychology of learning and motivation: Inference and text comprehension.* New York: Academic Press.
Swinney, D., Zurif, E., & Nicol, J. (1989). The effects of focal brain damage on sentence processing: An examination of the neurological organization of a mental module. *Journal of Cognitive Neuroscience*, *1*, 25–37.
Swinney, D., Zurif, E., Prather, P., & Love, T. (1996). Neurological distribution of processing operations underlying language comprehension. *Journal of Cognitive Neuroscience*, *8*, 174–184.

Tabossi, P. (1988). Accessing lexical ambiguity in different types of sentential contexts. *Journal of Memory and Language*, *27*, 324–341.

Thompson, C. K., Ballard, K. J., & Shapiro, L. P. (1997). *The role of complexity in training wh-movement structures in agrammatic aphasia: Optimal order for promoting generalization*. Paper submitted for publication.

Thompson, C. K., & Shapiro, L. P. (1995). Training sentence production in agrammatism: Implications for normal and disordered language. *Brain and Language*, *50*, 201–224.

Thompson, C. K., Shapiro, L. P., Ballard, K. J., Jacobs, B. J., Schneider, S. S., & Tait, M. E. (1997). Training and generalized production of wh- and NP-movement structures in agrammatic aphasia. *Journal of Speech, Language, and Hearing Research*, *40*, 228–244.

Wayland, S., & Taplin, J. E. (1985). Feature-processing deficits following brain injury. *Brain and Cognition*, *4*, 356–376.

Zurif, E., & Swinney, D. (1994). The neuropsychology of language. In M. A. Gernsbacher (Ed.), *Handbook of psycholinguistics.* Orlando: Academic Press.

Zurif, E. B., Swinney, D., Prather, P., Solomon, J., & Bushell, C. (1993). An on-line analysis of syntactic processing in Broca's and Wernicke's aphasia. *Brain and Language*, *45*, 448–464.

Received August 8, 1997
Accepted December 15, 1997

Contact author: Lewis P. Shapiro, PhD, San Diego State University, Department of Communicative Disorders, 5500 Campanile Drive, San Diego, CA 92182-1518
Email: Shapiro@mail.sdsu.edu

Key Words: sentence comprehension, aphasia, online, psycholinguistics