Cognitive Science Online, Vol.1, pp.8-21, 2003 http://cogsci-online.ucsd.edu

Tapping into the continuum of linguistic performance: Implications for the assessment of deficits in individuals with aphasia

Suzanne Moineau

Joint Doctoral Program in Language and Communicative Disorders
University of California San Diego and
San Diego State University
smoineau@crl.ucsd.edu

Abstract

The fundamental goal of every speech and language clinician is to provide services that will enhance the functional communicative abilities of the patients they treat. The cornerstone of developing a successful intervention program is careful patient assessment. Historically, clinicians have relied on traditional standardized language and neuropsychological assessment tools to determine performance baselines from which to plan the treatment course. Although informative in many ways, the batteries that are used can also be limiting. Most often they force clinicians and researchers into forming categorical diagnostic groups, which may result in the loss of critical information essential for the planning of therapeutic interventions. The purpose of the current paper is to review some empirical evidence that suggests we should strongly consider redefining classic syndromes, redesigning standard assessment tools, and utilizing new technologies to map out the symptom space in individuals with brain injury.

Introduction

In 1861, Paul Broca published an historically influential paper that aimed to systematically map behavioral symptoms to particular brain regions. Specifically, Broca claimed that the third convolution of the left frontal lobe was the seat of articulate speech, and that damage to this area would result in a defect in the motor realization of language (Goodglass, 1993). Soon after, Broca's aphasia became widely accepted as an impairment in the production of language resulting in a patient having non-fluent speech output but intact auditory comprehension. The patient thus exhibits an apparent ability to fully understand directives, questions and even simple conversation despite speech production that is telegraphic, primarily consisting of content words, and noticeably labored. Although the last 40 years have brought about minor revisions in this classic definition (i.e., auditory comprehension deficits can be seen, but only with complex syntax and grammar (Grodzinsky, 1995, 2000)), the core of the classification remains unchanged. Likewise, the cognitive and behavioral deficits associated with left temporal lobe damage, as outlined by Carl Wernicke, have undergone very little, if any, revision since 1874. Damage to this area of the brain typically results in deficits in comprehension of spoken language, however, as non-speech sensory images are purportedly intact, the Wernicke's aphasic demonstrates fluent, albeit paraphasic speech output. A patient with this classic profile typically suffers from an inability to comprehend even the simplest of linguistic stimuli (e.g., 'Is your name Bob?' or 'Touch your nose'). Also, despite having the natural flow and contours of normal speech production, the Wernicke's aphasic frequently produces non-words or misuses words in a given context. Though current diagnostic categories are grossly sufficient in describing the prototypical syndrome characteristics, a vast number of individuals with aphasia do not 'fit' these prototypes. This early observation fueled numerous debates, which continue to this day, about the nature of brain organization for language production and comprehension.

Despite strong evidence from the start against the theory that the brain comprises discontinuous sensorimotor centers and connections, this was the dominant view up until the latter half of the twentieth century (summarized in Kean, 1985)[1]. This view was then replaced (at least in some scientific circles) by another theory that had equally strong ties to the claim that brain areas are discontinuous by nature. However, the new account shifted from holding that these centers are separated along distinct sensorimotor lines to the notion that they are differentiated along content lines (i.e. grammar vs. lexicon, Caramazza, Berndt, Basili & Koller, 1981). Either way, the predominant view over the last 150 years has been one of discontinuous centers and mental organs which are localizable and domain specific. This view also holds that the deficits resulting from damage to such centers are easily distinguishable from one another and are able to be classified into distinct categories. It is out of these theories about brain organization for language, the autonomy of linguistic structures from one another and from all other cognitive functions, and specific competence and performance patterns following neurologic insult that aphasia subtypes and classifications were born. It is also with these same theories in mind that we design diagnostic tools with which to assess linguistic function and build our treatment plans.

Today, although most clinicians in the trenches would readily agree that the symptoms observed in aphasia are more accurately defined as continuous rather than discrete, as evidenced by the lack of 'pure' cases and the high proportion of unclassifiable patients, our standard assessment tools do not adequately reflect our understanding of this complex terrain of linguistic deficits. Instead, we continue to utilize and rely on tools that give composite scores and provide classifications as a way to conveniently define the linguistic behaviors that we are observing. By fitting all outliers into one or another syndrome type we fail to refine our diagnostic tools and criteria so that they are sensitive to and reflect the actual nature of language processing, which through strong evidence appears to be continuous and dynamic.

We do, however, have the means by which to more accurately measure, and thus define, the unique symptom space that every individual with aphasia occupies. These

---

[1] A more 'holistic' or distributed alternative to the centers-and-connections view has been offered throughout the modern history of aphasia -- from Freud, Hughlings Jackson, Pierre Marie, Arnold Pick, Kurt Goldstein, Henry Head, and in more recent times, by researchers like Hermann Kolk, Claus Heeschen and (as cited) Sheila Blumstein. It is just the case, however, that the *predominant* view, at least in Anglo-American circles, has been the modular one.

methods include investigating the nature of real-time lexical processing via on-line priming studies, processing in 'noisy' environments, and implicit processing as measured by event-related potentials (ERPs) and eye movements. These techniques can assist us in more precisely outlining profiles of processing strengths and weaknesses which can help us in designing effective intervention plans, and they are also more ecologically valid than traditional standardized tests. Though most of these techniques are still in the beginning stages of implementation with clinical populations, and have found their primary utilization in the research community, their systematic clinical application is essential if we are to do the greatest service to our patients. They enable us to uncover vulnerabilities in the system that may have otherwise gone undetected and as well, capture preserved implicit processing in individuals with severe deficits who, due to linguistic or physical limitations, may not be able to comprehend and/or perform even the simplest of explicit tasks. For example, both lexical priming studies and experiments investigating the effects of acoustic degradation on speech processing have led to the discovery that lexical activation and single word comprehension are not fully intact in Broca's aphasia, as once thought. On the flip side, recent work in neuroimaging has provoked some researchers to conclude that both Wernicke's and global aphasics, who may be reported to have no explicit comprehension of linguistic stimuli, may have preserved implicit semantic priming. Below is a summary of some of the work being done in these fields to better define the processing landscape of individuals with aphasia.

Lexical Processing via Priming Studies

A classic view of lexical-semantic impairments in individuals with aphasia would predict that Broca's aphasics are largely unaffected in this domain, while Wernicke's aphasics demonstrate severe deficits in lexical-semantic processing (Zurif, Caramazza, Myerson, and Galvin, 1974; Goodglass & Baker, 1976). In other words, Broca's aphasics have been considered to have an intact ability to activate and integrate lexical items, as evidenced by 'spared' comprehension of content words, while Wernicke's aphasics have been claimed to have deficiencies in this domain as noted by their failure to comprehend even simple, common lexical items. These views arose, however, mainly from measurements that required subjects to perform explicit judgment tasks, such as those presented in standardized tests. It was not until the 1980's that the accepted overall picture of intact lexical processing in Broca's aphasics began to be challenged. Initially, neuropsychological studies used a priming paradigm to investigate the integrity of the lexical-semantic system in individuals with aphasia, which provided evidence that neurologically intact individuals are faster and more accurate to perform a lexical decision task (i.e. to decide if a presented utterance is a real word or a non-word) following a primed word that is related to the target than to an unrelated word (Milberg and Blumstein, 1981; Blumstein, Milberg & Schreir, 1982; Milberg, Blumstein & Dworetzky, 1987, 1988). Contrary to what might be predicted of Broca's aphasics, however, the majority of the evidence revealed abnormal priming patterns in these patients. A few examples of the nature of the differences follows:

In their work, Milberg and colleagues (1988) found a group of Broca's aphasics to have reduced activation of lexical targets following the presentation of a phonologically altered prime (i.e., "gat" - "dog" vs. "cat" - "dog"). In other words, when the prime was a good production (having accurate place, manner and voiceonset time) Broca's aphasics demonstrated normal priming; however, if the prime was a poor exemplar (altered along one of these dimensions) they showed reduced priming as compared to normal control subjects. More recently, Utman, Blumstein and Sullivan (2001) found a similar effect in a new group of individuals with Broca's aphasia. Like the results obtained by Milberg, *et al.*, these Broca's aphasics demonstrated a larger and longer-lasting reduction in semantic priming in response to word-initial acoustic manipulations when compared to normal controls.

Swinney, Zurif & Nicol (1989) demonstrated that Broca's aphasics fail to show exhaustive access of secondary meanings of ambiguous words. Instead, the subjects they tested only accessed the most frequently occurring meaning, independent of contextual bias: a finding not seen in young adults, the elderly or fluent aphasics, who automatically primed all meanings of ambiguous words. An earlier study conducted with normal college students revealed, however, faster activation times for the primary meaning of an ambiguous word than for its secondary meanings, independent of context (Simpson, 1984). Given this finding, Swinney, *et al.*, speculated that Broca's aphasics may just have a slower-than-normal time course of meaning activation, with a corresponding failure to activate meanings beyond the most frequent one.

This *speed* of activation account of the deficits seen in lexical activation in Broca's aphasics has found further support through work conducted by Penny Prather and colleagues (Prather, Zurif, Stern & Rosen, 1992; Prather, 1994; Prather, Zurif, Love & Brownell, 1997). Prather, *et al*. demonstrated that Broca's aphasics do in fact show automatic priming, with normal decay, however the time course is protracted. In contrast to normal elderly controls who prime at relatively short interstimulus intervals (ISIs) beginning at 500 ms, Broca's aphasics show reliable automatic priming only at ISIs of 1500ms.

From the evidence accumulated from on-line priming studies it is becoming clear that Broca's aphasics do show deficits in lexical access as compared to normal control subjects, a finding that is rarely apparent in single word comprehension tasks where reduced speeds and incomplete activation may not be very sensitive in revealing underlying deficits. These studies did more than just uncover deficits in the lexical-semantic processing of Broca's aphasics, however. They uncovered some priming effects of lexical items in Wernicke's aphasics that more closely resembled normal controls than the priming seen in Broca's aphasics. In particular, Blumstein et al (1982) and Milberg (1987) found that unlike Broca's aphasics, Wernicke's aphasics prime poor exemplars, while Prather *et al.* (1997) found that their subject with Wernicke's aphasia showed a normal, rapid initial activation. While all studies also revealed differences between the priming of Wernicke's aphasics and normal controls (i.e., Wernicke's tend to hyper-prime distant exemplars and have abnormally long ranges of priming), classic taxonomies would suggest that on a lexical task, Broca's aphasics would show more normal patterns of processing than Wernicke's aphasics. This however does not appear to be the case.

Processing In 'Noisy' Environments

When first initiated, much of the work being done studying language deficits focused on the differential effects of acoustic degradation (distortions of the speech signal) on spoken language processing in aging and hearing impaired populations, as compared to normal, healthy young adults (Dirks, Morgan & Dubno, 1982; Helfer & Wilber, 1990; Gordon-Salant & Fitzgibbons, 1993, 1995, 1997). Soon after, however, this experimental paradigm began to be used to test a very different type of theory from the ones initially investigated.

As evidence began to mount against a theory of autonomous, domain-specific linguistic modules that can be independently impaired in individuals following stroke, accounts predicting reductions in processing resources and verbal working memory as the cause of processing breakdowns in aphasia began to be proposed (Just & Carpenter, 1992; Caplan & Waters, 1999).[2] Theories such as these suggested that any individual facing a reduction in resources may be susceptible to breakdowns in processing. In 1991, Kerry Kilborn set out to test this very hypothesis. He predicted that subjecting normal, healthy individuals to noise, and thereby reducing their general processing resources, could create isolated deficits in specific grammatical features. The deficits he induced in normal controls mirrored the performance of a group of German Broca's aphasics who were tested in a similar sentence interpretation task by Bates, Friederici and Wulfeck (1987). In short, the acoustic manipulation caused a selective breakdown in the processing of grammatical morphology, and an increased reliance on word order.

Since the time of this initial research by Kilborn, a flurry of similar studies have been conducted to investigate the vulnerability of different grammatical, syntactic and lexical structures to 'noise' (Miyake, Carpenter, & Just, 1994; Blackwell & Bates, 1995; Utman & Bates, 1998; Dick, Bates, Wulfeck, Utman, Dronkers, Gernsbacher, 2001). In these experiments, subjects were required to process linguistic stimuli (presented either via auditory or visual modality) under any one or more of the following experimental conditions: digit load manipulations, speeded presentation, or filtering of the speech signal. The findings of such studies converge along similar lines: the vulnerability seen in individuals with aphasia can be reproduced in neurologically intact individuals under a range of compromising processing conditions. These studies have, however, tested the effects of acoustic degradation on more complex structures than just the single lexical item, and have focused on deficits seen in normal controls. However, this experimental paradigm appeared to be ideal for investigating the vulnerability of single word comprehension in Broca's aphasics, who have historically been considered to be intact in this domain (Berndt & Caramazza, 1999). Though evidence from the lexical priming literature clearly reflects deficits in the lexical access system of Broca's aphasics, priming is a measure that may quite possibly be more indirect than a simple, direct single word lexical comprehension task.

In 2001, an experiment was conducted in our laboratory to assess the effects of acoustic degradation on single word comprehension in a group of elderly controls, right-hemisphere-damaged (RHD) individuals and individuals with aphasia (Moineau & Bates, 2001). The results indicated the following: when presented with unaltered speech, Broca's aphasics are as accurate as neurologically intact, age-matched adults at identifying whether or not a single spoken word correctly matches a visually presented picture. That is, under optimal listening conditions, such as those present in a standardized testing room, Broca's aphasics appear to have intact single word

[2] While Caplan & Waters do propose that there are different resources for syntax and all other language-related resources, they support the view that the deficits seen in individuals with aphasia are due to processing limitations rather than damage to a specific linguistic structure.

comprehension skills. Furthermore, as predicted by the traditional classification models, the group of Wernicke's aphasics tested in this experiment was the only population to demonstrate a significant comprehension deficit in the unaltered condition. When the stimuli were altered, however, the group of Broca's aphasics demonstrated significant decreases in accuracy as compared to elderly controls and RHD individuals. Their performance did not, however, differ significantly from that of anomic aphasics or Wernicke's aphasics. This pattern revealed a gradient of diminished performance that was based on group severity: Wernicke < Broca < Anomic < RHD < Elderly.

In summary, this experiment demonstrated that the range of deficits seen in aphasic patients when performing even a simple, single word comprehension task is continuous and fragile. Given the fact that we are most often processing speech with some type of environmental noise in the background, the conditions presented in this study appear to be more consistent with natural processing settings than the conditions under which we engage in standardized testing. This study reveals a gradient of performance that can be easily uncovered when we subject individuals to exogenous stressors that mimic common environmental conditions, and may also serve to simulate endogenous alterations in the processing climate following stroke.

To summarize thus far, evidence has accumulated to suggest that discrete classifications of symptoms as 'present' or 'absent' should be abandoned in favor of diagnostic criteria that respect the true nature of language impairments as they vary along a continuum from mild to severe. Patients who do not "have" the impairment in question under traditional classification schemes will show vulnerabilities when their processing abilities are pushed to the limit. Indeed, this gradient approach to processing deficits extends to normal, neurologically intact adults, whose performance resembles that of brain-injured patients when the processing climate is altered through exogenous stressors that mimic conditions of brain damage. Let us turn now to the other side of the coin: studies demonstrating spared (residual) abilities in patients who (by classic criteria) are believed to have lost the ability in question.

Implicit Processing: Event Related Potentials

To date, there is a substantial body of research that has utilized event related potentials (ERPs) to investigate the neural bases of cognition and language in both healthy, normal adults and those with neurologic damage (Neville, 1980; Kutas & Van Petten, 1994; Rugg, 1995; Hagoort, Brown & Swaab, 1996; Revonsuo & Laine, 1996; Swaab, Brown & Hagoort, 1997; Friederici, Hahne, von Cramon, 1998; Swaab, 1998; Swaab, Brown & Hagoort, 1998; Connolly, Mate-Kole & Joyce, 1999; Connolly, Major, Allen, & D'Arcy, 1999; Friederici & Jacobsen, 1999; Friederici, vonCramon & Kotz, 1999; Connolly & D'Arcy, 2000). Of particular interest in the investigation of language processing is the N400 effect. This effect was first discovered in 1980 by Kutas and Hillyard. In their study, Kutas and Hillyard found that a negative deflection in the ERP waveform was evident between 380-440 milliseconds following the presentation of a semantically anomalous word in a sentence context. The difference between the amplitude of the N400 to the semantically congruous versus the incongruous word is considered the N400 effect. This methodology is particularly useful in the assessment of individuals with aphasia as it does not require overt responses, and is capable of measuring brain activity during the normal continuous stream of speech, without interruption.

One of the first studies to investigate ERP effects in individuals with aphasia was carried out by Revonsuo & Laine (1996). The subject in their case study was noted to have a lesion that involved the entire region of Broca's area, part of Wernicke's area, and included the insula and underlying white matter. The authors began testing the subject 2.5 months post onset. He was reported to be globally aphasic, as measured by the standardized Finnish version of the Boston Diagnostic Aphasia Examination (Laine, Goodglass, Niemi *et al.*, 1993) at one week post onset. Prior to examining the N400 effect, a sentence categorization task revealed chance level performance for explicit comprehension. The authors presented the subject with 400 test items: 200 congruent and 200 anomalous sentences. Results indicated a pattern of performance consistent with normal controls. The subject in this study demonstrated a significantly greater negativity, occurring at approximately 400 ms after the presentation of the target word, for anomalous words as compared to congruent words.

In another study of implicit processing in a global aphasic, Connolly, *et al.* (1999) found similar findings to that of Revonsuo & Laine. The subject in their study was reported to be severely compromised by his injuries and was not indicated for rehabilitation. Formal, traditional assessment could not be conducted as the patient was not capable of performing the explicit tasks required. The authors tested the N400 effect to 320 sentences: 160 presented in the visual modality and 160 presented in the auditory modality. They found that their subject exhibited brain response patterns indicative of intact implicit processing. Comparisons to a control group revealed that the grand average for the aphasic subject did not differ significantly from the group of control subjects. This finding led to a reinstatement of individualized rehabilitative intervention, with a successful outcome.

In 1996, Hagoort and colleagues (Hagoort, Brown & Swaab, 1996) conducted a larger scale study, looking at the N400 effect in a group of 20 aphasic patients. Their goal was to see if there was a difference in the N400 effect : 1) based on aphasia syndrome (Broca's vs. Wernicke's); 2) based on severity (as measured by scores on comprehension subtests independent of syndrome classification); and 3) between aphasics and normals. The results indicated the following: 1) There was no significant difference in the N400 effect based on aphasia syndrome. The Wernicke's aphasics did show a larger reduction in the size of the N400 effect, as compared to the Broca's aphasics, however, this effect was not significant; 2) There was a significant difference noted in the N400 effect based on severity of symptoms. Individuals that were rated as low comprehenders, based on comprehension scores obtained via the Aachen Aphasia Test, showed significant reductions in the N400 effect as compared to high comprehenders and normal controls. The latter two groups did not differ materially from one another; and 3) Despite reductions in the overall N400 effect for the aphasic group as whole, they did not differ significantly from the control group.

In a subsequent study, Swaab and colleagues again looked at the differences in the N400 effect between brain-lesioned and neurologically intact individuals (Swaab, Brown & Hagoort, 1997). In this study, however, the authors compared their aphasic subjects solely based on comprehension severity (i.e., mild vs. moderate-severe impairment) and not based on classification type as in the previous study. In addition, they added a group of non-aphasic patients with right hemisphere damage. Again, results indicated that aphasics with only a mild comprehension deficit show N400 effects that are not significantly different than normal, elderly controls. The non-aphasic, right hemisphere damaged patients also showed normal N400 effects. Only the group with moderate to severe deficits in comprehension showed significant reductions in amplitude and delayed peak latencies in the N400 waveforms.

Finally, Friederici and colleagues most recently (Friederici, Hahne, & von Cramon, 1998; Friederici, von Cramon, & Kotz, 1999) used ERPs to investigate assumptions about automatic versus controlled parsing processes in individuals with brain lesions. In the earlier of the two studies, Friederici and colleagues looked at the early left anterior negativity (ELAN), N400 and P600 effects in two patients: one with Broca's aphasia and the other with Wernicke's aphasia (Friederici, Hahne, & von Cramon, 1998). While the N400 effect appears to reflect semantic processes, the ELAN and P600 effects have been found to correlate with syntactic phrase structure violations and syntactically non-preferred structures or outright syntactic violations, respectively (ELAN: Neville, Nicol, Varss, Forster, & Garrett, 1991; Hahne & Friederici, 1999; P600: Osterhout & Holcomb, 1992; Hagoort, Brown, & Groothusen, 1993). Friederici, *et al.* found that the Broca's aphasic showed both an N400 and a P600 effect, however, did not show the early negativity (ELAN) typically seen in normal controls. On the other hand, the Wernicke's aphasic showed the early negativity and the P600 component, however, he did not show an N400 effect. Despite some variation from normal controls, their patients did show some normal patterns of implicit activation.

Though in its early stages of inception as an assessment tool for individuals with aphasia, the technique of using ERPs as a diagnostic index of processing deficits has already provided evidence of its benefits in the assessment and therapeutic processes. In revealing that a patient demonstrated implicit processing, despite an inability to comprehend and perform basic explicit tasks, one group of researchers was able to extend rehabilitation services for an individual, and ultimately achieve success with auditory comprehension tasks. Though yet to be investigated, this technique may also be useful in predicting recovery patterns. At a minimum, it has provided evidence that, at least initially, something of the signal is being processed in a relatively normal fashion. As the "severely-impaired" subjects tested by Hagoort and colleagues (1996) did show different patterns of brain activity for congruous versus anomalous stimuli, that are consistent with patterns observed in normal controls, and as the Wernicke's aphasic tested by Friederici, *et al*. (1998) showed an intact ELAN waveform, it may be reasonable to conclude that some recognition is taking place, and that the breakdown occurs somewhere further along in the processing stream.

Implicit Processing: Head-Mounted Eye Tracker

In the same vein as ERPs, eye tracking techniques have begun to be proposed as a way to index implicit processing in individuals with aphasia. The first empirical study to link eye movements to spoken-language comprehension was conducted by Cooper in 1974. The main finding of Cooper's work was that eye movements to pictures were closely time-locked to semantically relevant information in a simultaneously presented spoken story. Despite the obvious far-reaching potential of this method in investigating language processing, interest in tracking eye movements quickly died off until the mid-1990's. It was not until 1994 that the head-mounted eye tracker was first presented, at the annual CUNY conference on sentence processing, as a research tool for use in investigating language processing (Tanenhaus, Magnuson, Dahan & Chambers, 2000). From that time on, numerous studies have been conducted to investigate a wide variety of empirical questions, including: which domains listeners consider when interpreting reflexives and pronouns (Runner, Sussman, & Tanenhaus, 2000); how argument structure is used in comprehending filler-gap dependencies (Sussman & Sedivy, 2000); how listeners use lexical conceptual knowledge as a way to predict upcoming information (Altmann, Haywood & Kamide, 2000); and what is the time course of reference resolution (Eberhard, Spivey-Knowlton, Sedivy, & Tanenhaus, 1995). As with ERPs, eye movement trackers allow for continuous measurements without disrupting the speech stream and do not require metalinguistic judgments, thus making them well-suited for use with neurologically impaired populations.

A thorough investigation of the literature in the eye-tracking domain failed to turn up any studies to date that were carried out with individuals suffering from aphasia. However, a pilot study conducted by Brooke Hallowell and colleagues (Hallowell, Wertz & Kruse, 2002), demonstrated that for a group of healthy young adults, eye movement fixation times indexed accurate comprehension of target times as measured on the Revised Token Test, a standard assessment tool used with neurologically impaired populations. As the authors did demonstrate consistency in the pattern of eye movement responses, patterns that could be correlated with successful auditory comprehension, this tool appears to be quite promising in its ability to assess the same auditory comprehension in populations not capable of overt responses. It is also a technique with all of the same benefits as the ERP for measuring implicit processing in severely compromised patients.

Discussion

As our knowledge of brain organization and function advances, so must our standard tools of assessment. We design elaborate tools that assist in furthering our understanding of the intricate workings of the brain, however, they often do not find their way into everyday clinical practice. It is not surprising that we do not rigorously utilize these techniques - the clinical community at large continues to hold on to outdated views about brain organization and language processing in individuals with aphasia. Our medical books and linguistic texts continue to map out syndromes as discrete entities that have limited overlap in symptomatology, despite the abundance of research that has provided much more evidence to the contrary - a point often left out of such textbooks. Though beneficial in providing a hint about the potential deficits one may expect to see in a given patient, classifications and aphasia quotients (obtained via standardized tests) should be interpreted with caution. They are not a foolproof way of determining the specific lesion site, array of distinct deficits, or underlying cause of communication failure (i.e., loss of knowledge, or deficient access).

By using assessment measures that can tap into real-time implicit and explicit processing, we have broadened our understanding of the nature of the breakdown in aphasia that goes beyond traditional classifications. We have discovered that Broca's aphasics are vulnerable to comprehension failures, even at the single word level. They show reductions in priming of the less frequent meanings of words as well as words that are not good exemplars. In addition, Broca's aphasics show a protraction in the time-course of lexical activation. Hence, the breakdowns seen in this population at the sentence and conversation levels may have more to do with lexical activation problems than was once suspected. As such, the patient may benefit from rehabilitative work on lexical comprehension at the single word level despite no overt deficits: designing tasks that require a subject to process single lexical items in noise, in speeded presentation or when the meaning may be ambiguous might possibly facilitate the recovery process.

These new tools sensitive to online processing, e.g. ERPs and eye-tracking, have also uncovered sparing of implicit processing in individuals with global and Wernicke's aphasia. Patterns of brain activity in these patients, as measured by the N400 effect, do not appear to be significantly different than normal controls. This discovery has extraordinary clinical implications. The finding that a patient may have intact implicit processing can mean the difference between treatment discharge and further intervention. It also has an impact on how we counsel families regarding what the patient may or may not be understanding. Furthermore, it may prove useful in mapping out recovery patterns. ERPs and eye tracking allow for different types of linguistic processing to be measured, and therefore can provide greater information about the nature of the deficit. For example, the N400 requires stimuli to be designed in an expected versus an unexpected condition, i.e., "He takes his coffee with cream and *sugar,"* versus "He takes his coffee with cream and *dog*." This provides information about whether or not the subject has expectations about the target given the context. Eye-tracking, on the other hand, allows one to ask and answer a question such as, "Does the patient know which circle is the *brown* one as opposed to the *blue* one?" by stating, "Look at the *brown* circle," and monitoring eye-movements. These data may provide useful information about which types of processing may remain implicitly intact, and which do not, as well as providing predictions about the long-term prognosis for recovery from deficits in different domains of processing.

As our knowledge of brain dynamics has evolved, so should our standard assessment tools. We have the methods with which to better assess our clients, and ultimately design more effective treatment plans. It is imperative that we begin to implement them into our every day clinical practice.

References

Altmann, G., Haywood, S., & Kamide, Y. (2000). Anticipating grammatical function: Evidence from eye movements. Paper presented at the *13th Annual CUNY Conference on Human Sentence Processing.* La Jolla, CA.

Bates, E., Friederici, A., & Wulfeck, B. (1987). Grammatical morphology in aphasia: Evidence from three languages, *Cortex, 23,* 545-574.

Berndt, R., Caramazza, A. (1999). How "regular" is sentence comprehension in Broca's aphasia? It depends on how you select the patients. *Brain and Language, 67,* 242-247.

Blackwell, A. & Bates, E. (1995). Inducing agrammatic profiles in normals: Evidence for the selective vulnerability of morphology under cognitive resource limitation. *Journal of Cognitive Neuroscience, 7,* 228-257.

Blumstein, S., Milberg, W., Shrier, R. (1982). Semantic processing in aphasia: Evidence from an auditory lexical decision task. *Brain and Language, 17,* 301-315.

Caplan, D. & Waters, G. (1999). Verbal working memory and sentence comprehension, *Behavioral and Brain Sciences, 22,* 77-126.

Caramazza, A., Berndt, R.S., Basili, A.G. & Koller, J. (1981). Syntactic processing deficits in aphasia. *Cortex, 17,* 333-348.

Connolly, J., Major, A., Allen, S., & D'Arcy, R. (1999). Performance on WISC-III and WAIS-R NI vocabulary subtests assessed with event-related brain potentials: an innovative method of assessment. *Journal of Clinical and Experimental Neuropsychology, 21,* (4), 444-464.

Connolly, J., Mate-Kole, C., & Joyce, B. (1999). Global aphasia: An innovative assessment approach. *Archives of Physical and Medical Rehabilitation, 80,* 1309-1315.

Connolly, J. & D'Arcy, R. (1999). Innovations in neuropsychological assessment using event-related brain potentials. *International Journal of Psychophysiology, 37,* 31-47.

Cooper, R. (1974). The control of eye fixation by the meaning of spoken language. A new methodology for the real-time investigation of speech perception, memory, & language processing. *Cognitive Psychology, 6,* 84-107.

Dick, F., Bates, E., Wulfeck, B., Utman, J., Dronkers, N., & Gernsbacher, M. (2001). Language deficits, localization and grammar: Evidence for a distributive model of language breakdown in aphasic patients and neurologically intact individuals. *Psychological Review, 108,* 4, 759-788.

Dirks, D., Morgan, D. & Dubno, J. (1982). A procedure for quantifying the effects of noise on speech recognition, *Journal of Speech and Hearing Disorders, 47,* 114-123.

Eberhard, K., Spivey-Knowlton, M., Sedivy, J. & Tanenhaus, M. (1995). Eye movements as a window into real-time spoken language comprehension in natural contexts. *Journal of psycholinguistic Research, 24,* 409-436.

Folstein, M., Folstein, S., and McHugh, P. (1979). Mini-Mental State Examination. *Journal of Psychology Research., 12:* 196-198.

Friederici, A., Hahne, A., & von Cramon, D. (1998). First-pass versus second-pass parsing processes in a Wernicke's and a Broca's aphasic: Electrophysiological evidence for a double dissociation. *Brain and Language, 62:* 311-341.

Friederici, A. , & Jacobsen, T. (1999). Processing grammatical gender during language comprehension. *Journal of Psycholinguistic Research, 28,* 467-484.

Friederici, A., von Cramon, D., & Kotz, S. (1999). Language related brain potentials with cortical and subcortical left hemisphere lesions. *Brain, 122,* 1033-1047.

Goodglass, H. (1993). *Understanding aphasia.* San Diego, CA: Academic Press.

Goodglass, H. & Baker, E. (1976). Semantic field, naming and auditory comprehension in aphasia. *Brain and Language, 3*: 359-374.

Gordon-Salant, S. & Fitzgibbons, P. (1993). Temporal factors and speech recognition performance in young and elderly listeners. *Journal of Speech and Hearing Research, 36,* 1276-1285.

Gordon-Salant, S. & Fitzgibbons, P. (1995). Recognition of multiply degraded speech by young and elderly listeners, *Journal of Speech and Hearing Research, 38,* 1150-1156.

Gordon-Salant, S. & Fitzgibbons, P. (1997). Selected cognitive factors and speech recognition performance among young and elderly listeners. *Journal of Speech, Language & Hearing Research, 40,* 423-431.

Grodzinsky, Y. (1995). A restrictive theory of agrammatic comprehension. *Brain and Language, 50,* 27-51.

Grodzinsky, Y. (2000). The neurology of syntax: Language use without Broca's area. *Behavioral and Brain Sciences, 23,* 1-71.

Hagoort, P., Brown, C., & Groothusen, J. (1993). The syntactic positive shift (SPS) as an ERP measure of syntactic processing. *Language and Cognitive Processes, 8,* 439-483.

Hagoort, P., Brown, C. & Swaab, T. (1996). Lexical-semantic event-related potential effects in patients with left hemisphere lesions and aphasia, and patients with right hemisphere lesions without aphasia. *Brain, 199,* 627-649.

Hahne, A., & Friederici, A. (1999). Functional neurotopography of syntactic parsing: Early automatic and late controlled processes. *Journal of Cognitive Neuroscience, 11,* 193-204.

Hallowell, B., Wertz, R., & Kruse, H. (2002). Using eye movement responses to index auditory comprehension: An adaptation of the Revised Token Test. *Aphasiology, 16,* 587-594.

Helfer, K., & Wilbur, L. (1990). Hearing loss, aging and speech perception in reverberation and noise. *Journal of Speech and Hearing Research, 33,* 149-155.

Just, M. & Carpenter, P. (1992). A capacity theory of comprehension: Individual differences in working memory. *Psychological Review, 99,* 122-149.

Kean, M.L. (1985). *Agrammatism.* Orlando, FL: Academic Press.

Kertesz, A. (1982). *Western Aphasia Battery test booklet.* New York: The Psychological Corporation.

Kilborn, K. (1991). Selective impairments of grammatical morphology due to induced stress in normal listeners: Implications for aphasia. *Brain and Language, 41,* 275-288.

Kutas, M. & Hillyard, S. (1980). Event-related potentials to semantically inappropriate and surprisingly large words. *Biological Psychology, 11,* 99-116.

Kutas, M. & Van Petten (1994). Psycholinguistics electrified: event-related brain potential investigations [Review]. In : Gernsbacher M., (Ed). Handbook of psycholinguistics. San Diego: Academic Press, pp. 83-143.

Laine, M., Goodglass, H., Niemi, J., Koivuselka-Sallinen, P., Tuomainen, J. & Marttila, R. (1993). Adaptation of the Boston Diagnostic Aphasia

Examination and the boston Naming Test into Finnish. *Scandinavian Journal of Logopedics and Phoniatrics, 18,* 82-93.

Milberg, W. & Blumstein, S. (1981). Lexical desision and aphasia: Evidence for semantic processing. *Brain and Language, 14,* 371-385.

Milberg, W., Blumstein, S., & Dworetzky, B. (1987). Processing of lexical ambiguities in aphasia. *Brain and Language, 31*, 138-150.

Milberg, W., Blumstein, S., & Dworetzky, B. (1988). Phonological factors in lexical access: Evidence from an auditory lexical decision task. *Bulletin of the Psychonomic Society, 26,* 305-308.

Miyake, A., Carpenter, P. & Just, M. (1994). A capacity approach to syntactic comprehension disorders: making normal adults perform like aphasic patients. *Cognitive Neuropsychology, 11,* 671-717.

Moineau, S. & Bates, E. (2001). Pushing the limits of word comprehension in normal and aphasic listeners. Unpublished manuscript.

Neville, H., Nicol, J., Barss, A., Forster, K. & Garrett, M. (1991). Syntactically based sentence processing classes: evidence from event-related brain potentials. *Journal of Cognitive Neuroscience, 3,* 151-165.

Osterhout, L. & Holcomb, P. (1992). Event-related potentials elicited by syntactic anomaly. *Journal of Memory and Language, 31,* 785-806.

Prather, P., Zurif, E., Stern, C., & Rosen, T. (1992). Slowed lexical access in nonfluent aphasia: A Case study. *Brain and Language, 43,* 336-348.

Prather, P. (1994). The time course of lexical activation in fluent and nonfluent aphasia. *Linguistics and Cognitive Neuroscience, 6,* 128-144.

Prather, P., Zurif, E., Love, T., & Brownell, H. (1997). Speed of lexical activation in nonfluent Broca's aphasia and fluent Wernicke's aphasia, *Brain and Language, 59,* 391-411.

Revonsuo, A. & Laine, M. (1996). Semantic processing without conscious understanding in a global aphasic: Evidence from auditory event-related brain potentials. *Cortex, 32,* 29-48.

Rugg, M. (1995). Event-related potential studies of human memory. In: Gazzaniga, M. (Ed.). The cognitive neurosciences*.* MIT Press, Cambridge, MA., pp 789-801.

Runner, J., Sussman, R., & Tanenhaus, M. (2000). Binding reflexives and pronouns in real-time processing. Poster presented at the *13th Annual CUNY conference on Human Sentence Processing,* La Jolla, CA.

Simpson, G. (1984). Lexical ambiguity and its role in models of word recognition. *Psychological Bulletin, 96,* 316-340.

Sussman, R. & Sedivy, J. (2000). Using eyetracking to detect and describe failed gap effects. Poster presented at the *13th Annual Conference on Human Sentence Processing.* La Jolla, CA.

Swaab, T., Brown, C. & Hagoort, P. (1997). Spoken sentence comprehension in aphasia: Event-related potential evidence for a lexical integration deficit. *Journal of Cognitive Neuroscience, 9,* 39-66.

Swaab, T. (1998). Event-related potentials in cognitive neuropsychology: Methodological considerations and an example from studies of aphasia. *Behavior Research Methods, Instruments & Computers, 30,* 157-170.

Swaab, T., Brown, C. & Hagoort, P. (1998). Understanding ambiguous words in sentence contexts: Electrophysiological evidence for delayed contextual selection in Broca's aphasia. *Neuropsychologia, 36,* 737-761.

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.

Tanenhaus, M., Magnuson, J., Dahan, D., & Chambers, C. (2000). Eye moevements and lexical access in spoken-language comprehension: evaluating a linking hypothesis between fixations and linguistic processing. *Journal of Psycholinguistic Research, 29,* 557-580.

Utman, J. & Bates, E. (1998). Effects of acoustic degradation and semantic context on lexical access: Implications for aphasic deficits [Abstract]. *Brain and Language, 65,* 516-518.

Utman, J., Blumstein, S., & Sullivan, K. (2001). Mapping from sound to meaning: Reduced lexical activation in Broca's aphasics, *Brain and Language, 79,* 444-472.

Zurif, E., Caramazza, A., Myerson, R., & Galvin, J. (1974). Semantic feature representations for normal and aphasic language. *Brain and Language, 1*, 167-187.