H

MECHANISMS OF INHIBITION IN WERNICKE'S APHASIA

by

DEBRA A. WIENER

A dissertation submitted to the Graduate Faculty in Speech and Hearing Sciences in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York

2000

UMI Number: 9986393

Bell & Howell Information and Learning Company
300 North Zeeb Road
P.O. Box 1346
Ann Arbor, MI 48106-1346

This manuscript has been read and accepted for the Graduate Faculty in Speech and Hearing Sciences in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

6-5-00
Date

Chair of the Examining Committee

8-2-00
Date

Executive Officer

Penny Prather, Ph.D.

Lisa T. Connor, Ph.D.
Supervisory Committee

THE CITY UNIVERSITY OF NEW YORK

Abstract

MECHANISMS OF INHIBITION IN WERNICKE'S APHASIA

by

Debra A. Wiener

Advisor: Distinguished Professor Loraine K. Obler

The aphasia literature supports a dissociation between automatic and controlled processing of lexical-semantic information in Wernicke's aphasia, with the evidence originating primarily from studies contrasting off-line conscious or controlled processing with on-line automatic processing. These findings suggest difficulty for individuals with Wernicke's aphasia in consciously operating on semantic information, but preserved automatic access. The first part of this present study involved a further look at controlled processing using an on-line task, a variation of the Stroop test, to investigate whether the underlying mechanism of inhibition is faulty at the controlled processing level.

The second part of the study involved re-examination of automatic processing, given recent findings (Prather et al., 1997) of an abnormal priming pattern associated with Wernicke's aphasia, suggesting an impaired inhibitory mechanism in the automatic processing realm. The Prather et al. List Priming Paradigm (LPP) was administered to a

larger subject pool to further examine lexical activation and deactivation in Wernicke's aphasia. The participants for both tasks were six adults with Wernicke's aphasia and twelve age- and education-matched normal controls.

Analysis of the Stroop reaction time and error percentage data confirmed an impairment of inhibition in Wernicke's aphasia. In addition, correlational analyses revealed that the magnitude of Stroop interference was significantly positively correlated with the clinical-behavioral symptom of severity of auditory comprehension deficits, as measured by the Token Test.

The LPP reaction time findings indicated that, although the average response times of the participants with Wernicke's aphasia were significantly longer than those of the normal controls, the two groups demonstrated a similar priming pattern. Both lexical activation and deactivation appeared preserved in Wernicke's aphasia. Furthermore, correlational analyses revealed no significant positive correlation between impaired Stroop inhibition and LPP priming, suggesting that performance on these two measures reflects different underlying processes.

In summary, neither slowed activation nor prolonged activation is the basis for the disproportionate impairment of auditory comprehension in Wernicke's aphasia. However, when controlled processing is demanded, the individual with Wernicke's aphasia cannot effectively ignore the automatically evoked, distracting stimulus, contributing to a reduction in attention allocation and in the resulting effectiveness of auditory processing.

Acknowledgments

Many years have led both directly and indirectly to the culmination of this project. Without the guidance of my longtime mentors, Dr. Martha Taylor Sarno and Dr. Karen Riedel, from the Rusk Institute of Rehabilitation Medicine, my interest in aphasia, on both an intellectual and emotional level, would not be what it is today. Your insight and compassion concerning the complexities of this devastating disorder have been an inspiration throughout my professional life. And to all the individuals with aphasia I grew to know throughout my years at Rusk, thank you for the depth with which you could share this portion of your lives with me. Your examples of strength and courage have contributed greatly to my own personal development.

To Dr. Loraine Obler, my advisor and chairperson, I can't begin to thank you for your guidance and support beginning with our first contact at the Graduate Center. Your professional enthusiasm and intellectual curiosity are inspirational. Thank you for the time you have devoted to shaping my interests and ideas throughout this entire academic process and for your demonstrated concern and respect.

To Dr. Lisa Connor, truly this dissertation would not be in its present form without your untiring commitment. I cannot thank you enough for all the hours you have spent with me, for your patience and mentoring in the field of cognitive science. You are such a fine teacher, and I am so grateful for our friendship.

To Dr. Penny Prather, thank you for your generosity in sharing your research experience, in fact, your research paradigm with me. I have learned so much over the past two years, and I appreciate your patience throughout the dissertation process.

There are many individuals to whom I owe thanks at the Boston University Aphasia Research Center. To Dr. Martin Albert, thank you for warmly welcoming me into your research center and for your generous support of resources for this project. To Dr. Edgar Zurif, special thanks to you, as well, for sharing your research paradigm and ideas. To Dr. Avron Spiro, thank you for your help in the overall statistical approach, and to Dr. Errol Baker, I am grateful for the many lunch hours you spent sharing your statistical expertise and patiently guiding me in specific implementation. To Dr. Kimberly Lindfield, thank you for your time and interest in serving as an outside reader. Thanks to Dr. Marjorie Nicholas and Dr. Patricia Fitzpatrick for guiding me towards enthusiastic participants. And a special thanks to research assistants Jennifer Green, Anna MacKay, Rachel Albert, and Anthony Valez, whose help was invaluable, particularly concerning computer programming.

My family has been greatly encouraging in this endeavor. My parents have always been the model of support, and I know how proud my dad would be of me today. Thank you, Mom, for all the years of love and confidence in my abilities. And to my husband, Elliott Dobin, you figuratively and literally have turned my life around. I am grateful for your continual pride and belief in me and for always listening. Thank you for providing me with the opportunity to complete this project on a full-time basis and for being my loving partner in our next full-time venture!

Table of Contents

List of Tables

List of Figures

Chapter 1

Introduction

Wernicke's aphasia, the most common of the fluent aphasias, is usually associated with a brain lesion in the posterior portion of the first temporal gyrus of the left hemisphere. The distinguishing characteristics of this syndrome are impaired auditory comprehension and fluently articulated, but paraphasic, speech (Goodglass & Kaplan, 1983). Syntax is described as "paragrammatic;" although grammar is not fully preserved, there is generally free usage of complex verb tenses and embedded subordinate clauses. There is a pressure of speech, with content evidencing a paucity of substantives, and errors characterized by sound transpositions, word substitutions, and perseverations. Auditory processing is always disturbed, but to varying degrees. As Wernicke's area is adjacent to the primary cortical auditory center, this location is theorized to play the role of association area for audition (Goodglass & Kaplan, 1983).

In the field of cognitive science, various models have been developed in an attempt to explain information processing in the normal adult population. Recently, these cognitive models have been applied to aphasic populations. Rather than considering the auditory comprehension deficit in aphasia strictly in terms of its linguistic nature, researchers have begun to examine the cognitive operations that may contribute to the language processing deficit.

Increasingly, aphasiologists have been focusing on the role that attention plays in difficulties in auditory processing. Whereas research findings support the presence of reductions in attention allocation in individuals with aphasia (Murray et al., 1997; Tseng

et al., 1993), the cognitive mechanisms behind these reductions remain unclear. The purpose of the present study is to investigate the extent to which the cognitive process of inhibition, at the lexical-semantic level of language processing, is impaired in Wernicke's aphasia.

Chapter 2

Review of the Literature

Language Processing Theory - Automatic and Controlled Processing

Many models of verbal memory describe the lexical-semantic system as an associative network with interlinked "logogens" (Morton, 1970) or "nodes" (Collins & Loftus, 1975) that represent concepts or features. The retrieval of information involves the activation of the relevant nodes, as theorized by the spreading-activation theory (Posner & Snyder, 1975; Schvaneveldt & Meyer, 1973). According to this theory, activation quickly and automatically spreads to adjacent, semantically related nodes but not to remote, semantically unrelated nodes.

Much of the evidence in support of an associative network and the spreading-activation theory comes from semantic priming studies. These studies typically involve a lexical decision task, in which a subject is asked to decide as quickly as possible whether a string of letters is a real word or not. A common finding is that subjects are quicker to judge a string of letters as a word when it is preceded, or primed, by a semantically associated word than by a semantically unrelated word. Semantic priming results in a facilitation of processing, indexed by faster response times and fewer errors.

Further experimental manipulation reveals a reduced or delayed response in certain conditions, providing evidence for the involvement of a second mechanism in language processing. This second mechanism, termed "controlled" processing, is theorized to operate in both isolation and in conjunction with automatic processing

(Posner & Snyder, 1975). Neely's classic (1977) experiment provides support for Posner and Snyder's (1975) two-process theory of attention. In this lexical decision paradigm, subjects were instructed that when the priming word was from one category (e.g., body parts), they should anticipate that the next word will likely be from another specified category (e.g., parts of a building), as the probability of this occurring will be great. The stimulus onset asynchrony (SOA) between onset of the prime and onset of the target letter string varied from 250 to 2000 ms. At the long (2000 ms) SOA, reaction times were faster with the expected pattern (e.g., *arm - door*) and slower when the target item was from the same category as the prime, relative to when the prime was a neutral cue (*XXX*). At the short (250 ms) SOA, however, reaction times were faster on trials where the prime and target were related and no different from the neutral condition when the prime and target were unrelated. Thus, based on these results, controlled processing is presumed to require time to be engaged.

Inhibition Theory

The facilitation effect evidenced at the short SOA is attributed to automatic spreading-activation. In contrast, at the long SOA, the effects of facilitation and *inhibition* are attributed to controlled processing. Within this interactive linguistic processing context, Berg and Schade (1992) clarify the term *inhibition*: "it is meant to describe in quantitative terms the negative effect the processing of a given item has upon the activation value of another item" (p.406). By definition, although facilitation can be evidenced in both automatic and controlled processing, inhibition is interpreted as invoking controlled processing exclusively. As Posner and Snyder (1975) explain, "once a subject invests his conscious attention in the processing of a stimulus, the benefit obtained from pathway activation is increased, and this benefit is accompanied by a widespread cost or inhibition in the ability of any other signals to rise to active attention" (p.66). Automatic processing is fast acting, occurs without intention, and does not demand attentional resources or interfere with other mental activity. In contrast, controlled processing is slow acting, is under an individual's voluntary control, and uses attentional resources and interferes with other tasks.

Theories of selective attention emphasize the role that the process of inhibition plays in suppressing irrelevant information for improved focus in such higher level cognitive tasks as language performance (Hasher & Zacks, 1988; Tipper, 1985). Traditionally, attention theories placed the emphasis on the target of selection. Unselected information was thought to passively decay (Broadbent, 1970). However, theories of selective attention propose an active suppression or inhibition of distracting information during selection for increased efficiency of processing.

Support for inhibition theory comes from the negative priming paradigm (Tipper, 1985). In such a task, a participant is asked to respond to a target item presented simultaneously with a similar distracter item. The critical manipulation in this task occurs between consecutive trials. The participant responds to a target on the test trial that had been ignored on the previous trial. The negative priming effect is lengthened response time on experimental trials as compared with control trials. The source of this slowing is theorized to be the inhibition that has accrued to the current target during its role as an ignored item in the previous trial.

Inhibitory function has been investigated in a variety of populations evidencing selection difficulties, including the elderly (Hasher & Zacks, 1988), schizophrenics (Maher, 1983), and patients with dementia of the Alzheimer type (Sullivan et al., 1995). As individuals with Wernicke's aphasia demonstrate a disproportionate impairment in language comprehension as compared with other cognitive abilities, they serve as an ideal population for the study of mechanisms of inhibition in lexical-semantic processing.

Lexical-Semantic Processing in Wernicke's Aphasia

A review of the aphasia literature reveals an overall consensus that individuals with Wernicke's aphasia demonstrate semantic impairments at the level of controlled processing. For example, Zurif et al. (1974) employed a task in which subjects were instructed to point to two of three written words that they felt were the most similar in meaning. The participants with Wernicke's aphasia performed poorly, being unable to categorize words, supporting the common clinical finding that when a patient with Wernicke's aphasia is required to explicitly manipulate semantic information, significant difficulties arise. The authors interpreted this inability to categorize as a disruption in the underlying organization of the lexicon, a theory that was supported by other studies at the time (Goodglass & Baker, 1976; Whitehouse et al., 1978).

In the 1980s, Milberg, Blumstein, and their colleagues conducted a series of experiments comparing automatic and controlled processing in Broca's and Wernicke's aphasia. In the first study (Milberg & Blumstein, 1981), participants were presented with a lexical decision task in which written words and nonwords were preceded by semantically related, unrelated, or nonword primes. There was a two-second interval between prime and target word presentation and a four-second interval between trials. A simple semantic-judgment task was later administered to the subjects, using the word pairs from the lexical decision task. This task was a metalinguistic task, involving overt decision about the relatedness of the pairs of words. They found that, despite a significantly longer latency of response for the participants with Wernicke's aphasia as compared with the Broca's group and the normal controls, the Wernicke's aphasics showed a significant priming effect, as did the normals. In contrast, the participants with Broca's aphasia did not show a reliable priming effect. For both aphasic groups, correlational analyses of magnitude of priming effect and semantic judgments did not reach significance, but revealed a negative trend. The authors concluded that the Wernicke's aphasic participants retained stored semantic information that could be automatically activated but was inaccessible to volitional, controlled processing. Although the slower reaction times of the individuals with Wernicke's aphasia suggested "some disturbance in the automatic activation of the semantic system" (p.382), it appeared that the semantic processing deficits did not lie at the level of underlying semantic organization.

In the second study, Blumstein et al. (1982) replicated the first experiment in the auditory modality. There was a 0.5-second interval between prime and target word display and an eight-second interval between each stimulus pair. The results revealed that all groups demonstrated significant semantic facilitation effects, regardless of whether performance was analyzed in terms of diagnostic group or comprehension level (as measured by the *Boston Diagnostic Aphasia Examination (First edition)*, Goodglass & Kaplan, 1972). The magnitude of the priming effect was not correlated with either comprehension ability or performance on the semantic-judgment task, whereas semantic relatedness judgments were found to have a significant correlation with severity of auditory comprehension deficit. These findings provided further support for a dissociation between automatic and controlled processing in Wernicke's aphasia, with the system of semantic organization appearing relatively preserved.

In a third study, Milberg et al. (1987) employed a task requiring a lexical decision on the third word of auditorily presented word triplets. The first and third words of each triplet were related to one, both, or neither meaning of the second, semantically ambiguous word (e.g., *bank*). There was a 0.5-second interval between each item within the triplet and an eight-second interval between each triplet. Results yielded facilitation effects for the contextually appropriate meaning of the ambiguous word for the participants with Wernicke's aphasia, similar to those of normal controls, despite more errors and slower reaction times. The participants with Broca's aphasia did not demonstrate semantic facilitation. These findings suggested a possible double dissociation in processing impairment between Broca's and Wernicke's aphasia, whereby there is impaired automatic activation with relatively preserved controlled processing in Broca's aphasia and relatively preserved automatic activation with impaired controlled processing in Wernicke's aphasia.

A number of studies have since found reliable automatic facilitation effects in individuals with Broca's aphasia (Chenery et al., 1990; Hagoort, 1993, 1997; Ostrin & Tyler, 1993), leading these authors to argue against an impairment of automatic activation in this population. Nevertheless, studies have continued to replicate the dissociation between automatic and controlled processing in Wernicke's aphasia. Chenery et al. (1990) replicated Blumstein et al.'s (1982) experiment, and Hagoort (1993) replicated Milberg et al.'s (1987) study, both studies obtaining similar findings for the participants with Wernicke's aphasia.

Inhibitory Function in Wernicke's Aphasia

Although the review of the literature, thus far, clearly points to a dissociation between automatic and controlled processing in Wernicke's aphasia, one cannot draw too many conclusions as to what mechanisms are faulty at the controlled processing level, given the measurement tool consistently utilized. All of these studies have used a semantic-judgment task in lieu of a controlled priming paradigm. As the judgment task is off-line, with the time course consisting of many seconds, it is unclear which cognitive processes may come into play for an individual during this unconstrained task. Only one study can be found in the literature comparing automatic and controlled processing of lexical-semantic information in Wernicke's aphasia utilizing real-time or on-line methods (Milberg et al., 1995). Although one other study, Henik et al. (1993), manipulated stimulus onset asynchronies to address the distinction between semantic and identity priming, the focus was on lesion site rather than aphasia type. None of their left-posterior participants were diagnosed with Wernicke's aphasia.

Milberg et al. (1995) administered two auditory lexical decision priming experiments to investigate the dichotomy between automatic and controlled processing in lexical access in Broca's and Wernicke's aphasia. In the first experiment, prime-target predictability was varied by preceding the actual test trials with an induction set, a series of word pairs in which either all real-word pairs were semantically related (high probability) or none of the real-word pairs were semantically related (low probability). The procedural intent was to maximize the likelihood that participants would use a semantically-based strategy in the high probability condition. The interstimulus interval (ISI) was held constant at 500 ms, a setting sufficiently long to invoke controlled processing in an auditory presentation. Both the young normal control group and the Broca's aphasics demonstrated semantic facilitation in the high probability condition. Both of these groups also demonstrated inhibition in the first half of this condition. In contrast, both the old normal control group (mean age 61.5 years) and the Wernicke's aphasics demonstrated semantic facilitation, but no evidence of inhibition.

In the second experiment, ISI was varied and set at 150 ms and 2000 ms, while prime-target predictability was held constant. Of the four subject groups, only the young normal controls showed an inhibition effect at the long ISI condition. Thus, in the one study available in the literature investigating inhibition in controlled processing of lexical-semantic information in Wernicke's aphasia, although inhibitory function appears reduced, it is unclear whether this reduction is due to the aphasia type or the impact of age. This distinction is an important one, as inhibition is shown to decrease with age (Balota et al., 1992; Hasher & Zacks, 1988), and Wernicke's aphasics are, on average, significantly older than individuals with other aphasia types (Obler et al., 1978).

In the neuropsychological literature, a common tool used to measure inhibition in non-aphasic populations is the Stroop Color-Word Test (Stroop, 1935). Although there are now many variations on this task, the basic design is such that a participant is asked to name the ink color of a printed word and ignore the meaning of the word. Ink color naming is slower when the ink color and the word meaning are incompatible (e.g., *blue* in red ink) than when they are compatible (e.g., *red* in red ink) or when they are neutral (e.g., *XXX* in red ink). The prevailing interpretation of this effect is that the word information is activated automatically, and the research participant needs to inhibit this information during the slower process of color naming (MacLeod, 1991). Greater interference on this task, as measured by the difference between reaction times to the incompatible versus neutral conditions, has been interpreted as reflecting reduced inhibitory abilities.

The aphasia literature contains very few studies of the Stroop effect, largely given the task's high verbal demands. The validity of measuring a cognitive function via a variable or unreliable verbal response is, obviously, questionable. The three studies found involving participants with aphasia have differing, yet specific goals. Wingfield et al. (1997) administered the Stroop test to an individual with focal brain atrophy with accompanying anomia and dyslexia. Their goal was to further investigate the processes involved in the Stroop effect, as the subject's speed of reading was no faster than his speed of color naming. Chmiel (1984) utilized a variation of the Stroop with a conduction aphasic to address the question of what role phonological recoding plays in accessing semantics during reading. The participant was required to sort Stroop cards into bins, labeled with either color patches or color names in black ink, under silent and concurrent articulation conditions.

In the most pertinent study to this current project, Revonsuo (1995) administered a computerized, manual-response version of the Stroop test to a participant with global aphasia and poor single-word reading comprehension. The objective of this study was to determine if single-word processing could occur despite the absence of subjective understanding of word meanings. The Stroop stimuli were presented in two colors (red or blue), and the participant was instructed to press one of two computer keys (one colored red and one colored blue) that matched the color of the stimulus on the screen. Not only did the aphasic individual demonstrate a Stroop effect, but the effect was larger than that evidenced by the age-matched normal controls (mean age 67.7 years), revealing greater interference and reduced inhibition with global aphasia.

In order to adapt the Stroop test for use with a Wernicke's aphasic population, a manual-response version appears necessary given the high frequency of verbal paraphasia associated with Wernicke's aphasia. MacLeod (1991) compiled an extensive review of studies investigating the Stroop effect since J. R. Stroop's classic 1935 article. MacLeod concluded that although the interference effect may be reduced when response modality is switched from oral to manual, it remains robust. A number of researchers (e.g., Fox et al., 1971; Shor, 1971; Windes, 1968) also have found that numbers can produce significant interference effects. For example, the naming of an Arabic numeral is interfered with when it appears in incongruent quantities. Use of numerical stimuli appear warranted in an adaptation of the Stroop test for Wernicke's aphasia, as they allow for a manual, computer keyboard response. Although use of these stimuli taps into the lexical-semantic level of language, they avoid the need for the participant's verbal response.

The first of three parts of my study involves administration of a computerized manual-response, numerical version of the Stroop test to individuals with Wernicke's aphasia and age-matched normal controls. The purpose of the experiment is to investigate whether inhibition in controlled processing of lexical-semantic information is impaired in Wernicke's aphasia and whether this impairment is due to the aphasia type or the impact of age.

The Time-Course of Lexical Activation in Wernicke's Aphasia

The second part of the study involves a further look at automatic processing. Whereas the literature review, thus far, has revealed relatively preserved automatic activation in Wernicke's aphasia, a recent study, employing somewhat different methodology, has revealed an abnormal priming pattern associated with Wernicke's aphasia. Prather et al. (1997) investigated the time-course of lexical activation in Broca's and Wernicke's aphasia. Their technique, the List Priming Paradigm (LPP), involves the continuous presentation of printed letter strings about which a participant is asked to make lexical decisions. There are no pauses between the letter strings that would pair words together as in the traditional pair priming paradigm. Thus, the LPP was designed to restrict priming to automatic effects by eliminating an expectancy generation strategy (Neely, 1991; Shelton & Martin, 1992) that could arise if participants notice the relationships between primes and targets. Embedded within the continuous list are associated word pairs; they are low in proportion to the total number of words and nonwords to further minimize strategizing. Using this paradigm, the ISI is inserted between each letter string and can be varied to determine the shortest and longest intervals at which priming occurs.

The LPP was administered to one individual with Wernicke's aphasia, JM, whose performance was compared to one participant with Broca's aphasia, as well as previously reported data from another participant with Broca's aphasia (Prather et al., 1992) and six age-matched normal controls (Stern et al., 1991). JM demonstrated priming as early as the normal controls, at an ISI of 300 ms. However, for the normal controls, loss of priming was evidenced within 300 ms of obtaining priming. This is what would be expected, given what is known about the time course of automatic and controlled priming effects (Neely, 1977). Controlled effects take longer to initiate than automatic effects but, once initiated, increase over time as they continue to be stimulated by the context. Automatic effects normally peak early and then diminish. JM continued to show significant priming effects at an ISI of 1100 ms, with loss of priming not evidenced until an ISI of 1500 ms. That is, priming based on automatic spreading-activation persisted for at least 800 ms after it was initially observed. The participants with Broca's aphasia, in contrast, evidenced slowed lexical activation, as priming was not observed until an ISI of

1500 ms; however, as with the normal controls, deactivation was evidenced within 300 ms of obtaining priming.

The question arises as to what may account for the delayed deactivation evidenced in the participant with Wernicke's aphasia. The deactivation of a system can be either a passive process or involve a second mechanism whose function is to halt the processing of the information. In an active realm, the process is one of inhibition, a mechanism that, traditionally, is ascribed solely to the controlled processing end of the spectrum. Thus, in this automatic processing context, we would be led to focus on a possible deficiency in the passive decay of the activation curve based on traditional theory. However, researchers are increasingly questioning the traditional controlled and automatic processing dichotomy (Rafal & Henik, 1994). In fact, Berg and Schade (1992) suggest the presence of three possible deactivational forces - decay, self-inhibition, and other-inhibition. "The core idea of self-inhibition is to have a node inhibit itself immediately after being selected for production" (p.409). As in passive decay, this would prevent the activated node from being selected repeatedly. However, "the effect of self-inhibition is absolute in that it brings a node's activational level down to zero rather than just attenuating it" (p.409).

Presently, one can only speculate as to how active or passive the deactivational process might be. Nevertheless, one can surmise that some mechanism that appears to be the counterpart to inhibition in an automatic processing realm appears faulty in Wernicke's aphasia. The second part of my study involves administration of the Prather et al. paradigm to a larger subject pool to further study the deactivation component of lexical activation in Wernicke's aphasia and normal age-matched controls. We will be able to compare these findings with performance of the same individuals on the Stroop test, looking at inhibition in controlled processing. If there is an active suppressant in the early stages of processing, we would expect a correlation between interference on the Stroop test and deactivation of priming on the LPP. If, on the other hand, there is no correlation between performance on these two tasks, a more passive deactivational process would be suggested.

Clinical-Behavioral Correlates

The final part of the study involves a clinical-behavioral correlation with the information obtained concerning automatic and controlled processing. Inhibitory deficits are theorized to contribute both to deficits in language processing and to symptoms of verbal perseveration. Recurrent perseveration, defined as unintentional repetition of a previous response to a subsequent stimulus, is a common symptom of Wernicke's aphasia (Albert & Sandson, 1986). Several researchers (Crider, 1997; Hudson, 1968; Shallice, 1988) have theorized that the basis for perseveration is a breakdown of an inhibitory system resulting in prolonged activation and, thus, involuntary recall of a lexical item. The present study correlates clinical measures of auditory comprehension and of recurrent perseveration with findings from the automatic and controlled processing paradigms for further understanding of the impact of inhibitory mechanisms in Wernicke's aphasia.

Perseveration in aphasia has been shown to be more readily elicited in some tasks than in others (Albert & Sandson, 1986). Two tasks frequently used to elicit verbal perseveration have been Word Fluency (Borkowski et al., 1967) and confrontational naming. Santo Pietro and Rigrodsky (1982) found that increasing rate of presentation in confrontational naming and increasing the semantic difficulty of items resulted in an increase in perseverations in the aphasic participants they tested. Furthermore, Vitkovich and Humphreys (1991) found, when testing non-aphasic, young adults, that more confrontational naming errors were made in speeded deadline conditions and in response to low-frequency target pictures that were preceded by semantically related high-frequency picture primes. In the present study, recurrent perseveration is measured by both the traditional Word Fluency test and by a rapid naming task that incorporates these prior findings concerning temporal and semantic factors for maximal elicitation of errors. Auditory comprehension is measured by administration of two traditional aphasia tests, the Token Test (DeRenzi & Vignolo, 1962) and the Complex Ideational Material subtest of the *Boston Diagnostic Aphasia Examination* (*BDAE*) (Goodglass & Kaplan, 1983).

Summary

The purpose of the study is to investigate the extent to which inhibition, at the lexical-semantic level of language processing, is impaired in Wernicke's aphasia. Two measures of inhibition are being utilized to address this investigation at two stages of processing. First, a variation of the Stroop test is employed to examine controlled processing, as the Stroop test has been a classic way to operationalize inhibition in non-aphasic populations. The second measure of inhibition is the List Priming Paradigm. The LPP allows us to assess automatic processing, as it was designed to minimize the anticipation component of performance that can occur in the traditional pair priming paradigm. In addition, given its design, varying ISIs can be inserted between each letter string to determine the shortest and longest intervals at which priming occurs. Using this paradigm, it is possible to examine not only lexical activation, but to assess the deactivation component of automatic processing. Finally, correlational analyses are being utilized to examine the relationship between the two measures of inhibition and the clinical-behavioral manifestation of impaired inhibition in verbal perseveration and reduced auditory comprehension.

Statement of Hypotheses

1. Individuals with Wernicke's aphasia will evidence impaired inhibition in processing of lexical-semantic information relative to age-matched, normal controls. On the Stroop test, the participants with Wernicke's aphasia will demonstrate greater difficulty than the control subjects in inhibiting an automatic response. The aphasic participants will demonstrate no significant difference relative to the normal controls in the facilitation effect, but significantly greater interference relative to the controls, reflecting an impairment in inhibition.

2. Individuals with Wernicke's aphasia will evidence impaired inhibition but preserved activation of lexical-semantic information relative to age-matched, normal controls. In the List Priming Paradigm, the participants with Wernicke's aphasia will demonstrate a prolonged period of activation of priming relative to the control subjects. The normal

controls will demonstrate priming effects at an ISI of 500 ms, but not at 1100 ms or 1500 ms. The participants with Wernicke's aphasia will demonstrate priming effects at 500 ms and at 1100 ms, but not at 1500 ms.

3. The two operational measures of inhibition (i.e., the Stroop test and the List Priming Paradigm) are tapping the same underlying processes. There will be a positive correlation between impaired inhibition on the Stroop test and delayed deactivation of priming in the participants with Wernicke's aphasia.

4. A behavioral manifestation of impaired inhibition is verbal perseveration. There will be a positive correlation when comparing the frequency of verbal perseveration with impaired inhibition on the Stroop test and delayed deactivation of priming in the participants with Wernicke's aphasia.

5. A behavioral manifestation of impaired inhibition is reduced auditory comprehension. There will be a positive correlation when comparing the severity of auditory comprehension deficits with impaired inhibition on the Stroop test and delayed deactivation of priming in the participants with Wernicke's aphasia.

Chapter 3

Methodology

Participants

Six adult participants with Wernicke's aphasia and twelve normal controls were tested. Participants were recruited from the subject pool of the Boston University Aphasia Research Center, which consists of both individuals who have sustained aphasia and normal adults.

The six participants with Wernicke's aphasia were selected based upon the following criteria: a single onset of a left posterior infarct post cerebral vascular accident, with no history of dementia; no history of prior neurological trauma, drug or alcohol abuse, or chronic psychiatric disorder; native and primary language being English; right-hand dominance; normal visual acuity, with or without correction; and normal hearing thresholds across the speech frequencies, with or without correction.[1] The diagnosis of Wernicke's or fluent aphasia was based upon clinical observation and language examination. Six subtests of the *Neurosensory Center Comprehensive Examination for Aphasia* (*NCCEA*; Spreen & Benton, 1969) were administered to each participant with aphasia: Visual Naming, Description of Use, Sentence Repetition, Word Fluency, Identification by Sentence (the Token Test), and Reading Names for Meaning (Pointing). To ensure adequate reading comprehension for purposes of this study, a screening criterion of a score of at least 9/10 on the Reading Names for Meaning subtest was

[1] Pure-tone audiometric screening was conducted at 40 dB. While Participant 6 failed the screening at 2000 Hz, evidencing bilateral hearing thresholds at this frequency at 55 dB, he was included in the study, as his hearing was deemed functionally adequate for purposes of the study.

established; all participants received full score on this subtest. The "Speech" and "Understanding" subsets of the *Functional Communication Profile* (Sarno, 1969) also were administered to each participant with aphasia for purposes of a comprehensive participant profile.

Table 1 summarizes the relevant demographic and clinical characteristics of the aphasic participants. All of these participants were male. Their mean age was 71.7 years, with a range of 63-76 years. Their mean level of formal education was 11.5 years, with a range of 10-12 years.

The twelve normal controls were selected by the following criteria: right hand dominance; native and primary language being English; normal visual acuity, with or without correction; normal hearing thresholds across the speech frequencies; no history of neurological trauma, drug or alcohol abuse, chronic psychiatric disorder, or dementia; a score of 28 or greater on the Mini-Mental State examination (Folstein et al., 1975); and normal single-word reading comprehension as demonstrated by full score on the Reading Names for Meaning subtest of the *NCCEA*. They were matched to the aphasic participants by age (mean age of 71.5 years, range 62-77 years) and level of formal education (mean of 12.6 years, range 12-16 years). Six of the control participants were male (Participants 7-12) and six were female (Participants 13-18).

Overall Design

The study consists of three experimental tasks. Each task was administered to every participant. In addition, three aphasia subtests were administered to all participants:

Table 1. Demographic and clinical characteristics of the participants with Wernicke's aphasia, including: chronological age; level of formal education; time post-onset of CVA in months; overall aphasia severity rating; range of percentiles of subtests of the *NCCEA* (Spreen & Benton, 1969) administered; and percentiles of estimated function in "Speech" and "Understanding" subsets of the *FCP* (Sarno, 1969).

Participant	Age	Education	Time post-onset	Aphasia severity	*NCCEA* subscores*	*FCP* speech**	*FCP* understanding**
Participant 1	72 yrs	12 yrs	177 mos	moderate	20 - 88 %ile	56%	57%
Participant 2	76 yrs	10 yrs	56 mos	mod-severe	20 - 61 %ile	49%	55%
Participant 3	63 yrs	12 yrs	163 mos	moderate	13 - 88 %ile	55%	58%
Participant 4	74 yrs	12 yrs	114 mos	severe	6 - 61 %ile	50%	50%
Participant 5	70 yrs	12 yrs	76 mos	severe	8 - 61 %ile	51%	49%
Participant 6	75 yrs	11 yrs	102 mos	mod-severe	8 - 61 %ile	49%	47%

*Percentiles are based upon an aphasic population.

**Percentile represents functional communicative effectiveness in this modality based upon estimated premorbid language proficiency.

Word Fluency, the Token Test, and the Complex Ideational Material subtest of the *BDAE.*

Testing of an individual participant took place over two to three separate sessions, each approximately forty-five minutes in length. For the participants with aphasia, Day 1 was comprised of screening measures, reviewing and signing the informed consent forms, and language testing. Day 2 consisted of administration of part 1 of task 2, followed by task 1. Day 3 involved administration of part 2 of task 2, followed by task 3. For the normal controls, Day 1 began with screening measures and reviewing and signing the informed consent forms, followed by part 1 of task 2, task 1, and Word Fluency. Day 2 began with administration of the Token Test and Complex Ideational Material, followed by part 2 of task 2, and task 3. For all participants, administration of the two parts of task 2 were separated by at least one week, but no more than two weeks.

Task 1 - Controlled Processing: The Stroop Test

Materials

In this adaptation of the Stroop test, Arabic numerals rather than the standard color words were utilized. In order to create a measure of facilitation and interference, three conditions were set up (see Appendix A). The neutral condition is represented by an "X" in its four possible quantities. The compatible condition is represented by the Arabic numeral presented in congruent quantities, consisting of four stimuli. The incompatible condition is represented by the Arabic numeral presented in incongruent quantities, consisting of twelve stimulus items. The three experimental conditions provide a measure of facilitation (compatible vs. neutral condition) and interference (incompatible vs. neutral condition).

The experimental task consists of 216 stimulus items, containing 72 items for each condition. In order for each condition to be equally represented, the stimuli in both the neutral and compatible conditions were tripled in quantity and then assigned random numbers along with the stimuli in the incompatible condition for random order presentation to each participant. In addition, presentation of the stimulus items was immediately preceded by three filler items to maximize a participant's response readiness for the actual experimental items. These filler items were chosen randomly to represent each condition and occur in random order for each participant.

The 10 practice items in this task were pseudo-randomly selected. They consist of three items randomly selected from the neutral condition, three items from the compatible condition, and four items randomly selected from the incompatible condition. The same set of practice items was administered to each participant in random order.

Procedure

Participants were seated at a comfortable distance in front of a Macintosh PowerBook 180 computer with a 10 inch black and white screen. On the attached keyboard, four keys were exposed labeled "1", "2", "3", and "4". Participants were instructed to press the key that corresponded to the quantity of items on the screen. They were told to respond as quickly as possible and directed to use their left hand only.

The stimuli were presented in black on a white background via the software package PsyScope (Cohen et al., 1993). Each participant was first directed through a practice trial of 10 stimulus items to ensure understanding of the task. This file of 10 items was repeated, when necessary, until comprehension of the task was demonstrated by three consecutive correct responses. The 216 stimulus items were randomly presented to each participant in one testing session. The software package recorded both the participant's response and response time. A button box was attached to the computer, via the modem output, to increase the timing accuracy from the Macintosh's internal timing mechanism, accurate to 17 +/- 4 ms on the PB180, to 1 +/- 4 ms using the button box. A stimulus item appeared on the screen and remained there until the participant depressed one of the four keys. The next item appeared on the screen 500 ms after the participant's response.

This variation of the Stroop test is modeled after Salthouse and Meinz's (1995) version, as it lent itself to modifications for increased validity in a language-impaired population. The differences between the two versions are primarily procedural. For purposes of the present study, a manual-response rather than a verbal-response mode has been implemented. The task has also been computerized for maximal response time accuracy.

Task 2 - Automatic Processing: List Priming Paradigm (LPP)

Materials

This task is modeled after the Prather et al. (1997) paradigm, with some minor revisions. These revisions include choice of stimulus items and the specific software upon which it is run. The stimulus items are listed in Appendices B, C, and D. The 96 experimental word pairs are composed of prime words and their semantically associated target words. Associates were selected on the basis of published norms (Jenkins, 1970; Keppel and Strand, 1970; Marshall and Cofer, 1970; Postman, 1970) plus data obtained by polling locally-based (New York and Boston) college-aged, middle-aged, and elderly adults for their first associates to prime words.[2] The final set of associates represents the experimenters' selections, based on those norms and polled associations, of a set of strongly associated lexical items. Each of the 96 control words that are paired with the experimental words are unrelated in meaning to the target word, but matched to the prime word in length and frequency (Francis & Kucera, 1982). For those words belonging to more than one grammatical class (e.g., *dream* being both a noun and a verb), the frequency count for the noun category was chosen given that the majority of words in the list are nouns. The guidelines for a frequency match were based upon inclusion in one of the four following categories: less than 50 (per million); 50-100; 100-250; and 250-500. Low frequency words were matched very closely, whereas high frequency words fall in a larger range as the difference between the familiarity of these words is not as great.

[2] Prather et al.'s (1997) stimulus selection involved the polling of several dozen college-aged and elderly adults. For the present study, twenty-one additional middle-aged and elderly adults in the New York and Boston areas were polled.

Two lists, I and II, were constructed using these 96 related and 96 control pairs. Each list contained 48 related and 48 control pairs. If the related pair for a particular target word was in the first list, then its matched control was in the second list, and vice versa, so that a target word occurred only once in list I and list II, either with the related or the control word preceding it. In addition, each list included 108 non-experimental filler words and 300 pronounceable nonwords, for a total of 300 words and 300 nonwords per list. The pronounceable nonwords were matched to the control and prime words in length and first letter distribution. The non-experimental filler words were matched to the control and prime words in length and frequency. The mean frequency of the filler words, the control words, and the prime words is 47 per million (Frances & Kucera, 1982). The filler words have a standard deviation of 63.6, a median of 26.5, and a range of 1 to 446. The control words have a standard deviation of 78.3, a median of 16, and a range of 1 to 471. The prime words have a standard deviation of 76.6, a median of 18, and a range of 1 to 413.

The lists were constructed by, first, a separate randomization of the target words, filler words, and the nonwords. These words were then divided into lists I and II. The three sets of sub-lists for list I were merged and randomized in blocks of 42, consisting of 8 target words, 9 fillers, and 25 nonwords. Primes and controls were assigned to list I and list II in alternating fashion, and those assigned to list I were added to list I, preceding each target. The word WORD was then added to list I on average once every 15 items. Inclusion of this repeated word was intended to distract participants from potentially watching for or noticing the occasional related pairs by providing a repeated event about which participants would more likely generate hypotheses.

The filler words and nonwords in list II were then merged and randomized in blocks of 34, consisting of 9 fillers and 25 nonwords. They were moved into the file with list I, and the remaining targets, primes, controls, and the words WORD were placed into the same position in list II as in list I.

The four sets of 10 practice items each contain four filler words and five pronounceable nonwords that were not used in the actual experiment, along with one presentation of WORD. The 10 practice items chosen for each set were pseudo-randomly distributed in each list. The larger file of 40 practice items is a compilation of the four lists.

Procedure

Participants were seated at a comfortable distance in front of the same Macintosh PowerBook 180 computer utilized in Task 1, attached to which was a button box placed on the table between the computer and the participant. The button box contained two buttons, the left black button labeled "no" and the right red button labeled "yes." The task was a lexical decision task, and participants were instructed to indicate whether the string of letters that appeared on the screen was a real word in English or not by depressing the appropriate button with their left hand. Throughout the task, participants rested one finger on each of the two buttons and were told to respond as quickly as possible. The letter string remained on the screen until a response was made, or for a maximum of 3000 ms.

The letter string was then removed from the screen, and the appropriate ISI was initiated. The ISI represents the elapsed time between the response to one word and the presentation of the next word.

The stimuli were presented in white on a black background via the software program LPP 2.4. The software driver accesses the Macintosh's internal clock for millisecond-level accuracy in timing stimulus onset, stimulus offset, and response latencies to make the lexical decision. Stimulus items include experimental words (where a target response is semantically associated with the prime word that precedes it), control words, filler words, and pronounceable nonwords. Semantic priming occurs when a participant's response to a target word preceded by a prime is faster than when it is preceded by a control word.

There are two experimental lists, each consisting of 600 stimulus items plus the word WORD appearing on average once every 15 items. Each list was administered to each participant during one of two testing sessions, which were spaced at least a week apart. The stimuli were programmed so that there are five rest breaks within each testing session. These rest breaks coincide with the end of the three ISI blocks that were examined: 500 ms, 1100 ms, and 1500 ms.

The experimental design controls for list order presentation from session one to session two. The design is also balanced to prevent a possible order effect of ISI presentation. Three ISI orders were chosen: Order 1 (500 ms, 1100 ms, and 1500 ms); Order 2 (1100 ms, 1500 ms, and 500 ms); and Order 3 (1500 ms, 500 ms, and 1100 ms).

Each participant served as his/her own control from session one to session two, as can be seen in the following outline:

Participant 1	Day 1: List 1, Order 1	Day 2: List 2, Order 1
Participant 2	Day 1: List 2, Order 1	Day 2: List 1, Order 1
Participant 3	Day 1: List 1, Order 2	Day 2: List 2, Order 2
Participant 4	Day 1: List 2, Order 2	Day 2: List 1, Order 2
Participant 5	Day 1: List 1, Order 3	Day 2: List 2, Order 3
Participant 6	Day 1: List 2, Order 3	Day 2: List 1, Order 3

For the twelve normal controls, this design was simply repeated.

Each testing session began with a set of 10 practice items administered at an ISI of 750 ms. If the participant did not appear to understand the task after these items were administered, further guidance and practice were provided via a practice file of 40 items. Once comprehension of the task was demonstrated by three consecutive correct responses, the experiment proceeded, and the appropriate list was administered. One hundred and seven stimulus items (including 7 presentations of the word WORD) were presented at the first ISI for that participant, followed by a brief rest break, the duration of which the participant controlled. One hundred and seven stimulus items were then presented at the second ISI, followed by a similar rest break. One hundred and seven stimulus items at the remaining third ISI were then presented, followed by a slightly longer break, during which time the second part of that list was loaded for administration. Presentation of the second part of the list replicated the first part in procedural design, and the three ISIs were once again tested in the same order. A practice session of 10 items similarly preceded the second part of the list.

Task 3 - Perseveration: Rapid Naming Task

Materials

The picture stimuli, accompanied by their target word responses and word frequencies (Francis & Kucera, 1982), are listed in Appendix E. The line drawings were taken from the standardized set of pictures by Snodgrass and Vanderwart (1980).[3] Each prime picture was chosen based upon: the relative high frequency of its name (30 per million or greater; Francis and Kucera, 1982); its inclusion in the Snodgrass and Vanderwart (1980) standardized picture set; it being unrelated semantically to the other four primes;[4] and its membership in a semantic category (Battig & Montague, 1969) large enough to generate three pictured, low frequency targets. The name of each target picture ranges from 24 to 236 per million less than its associated prime. Five additional pictures whose names are of relative low frequency (less than 24 per million; Francis & Kucera, 1982) and are unrelated semantically to the other pictures (Battig & Montague, 1969) complete the set of stimuli.

---

[3] The target item "bench" is an exception, its source being Abbate and LaChappelle (1978). When reproduced in this experiment, it was matched to scale to the Snodgrass and Vanderwart (1980) pictures.

[4] The stimulus item "horse" is an exception, as it is ranked 32 in order of response to the category "vehicle" (Battig & Montague, 1969).

Procedure

Participants were seated at a comfortable distance in front of the same Macintosh PowerBook 180 computer utilized in Task 1 and Task 2. A line drawing of an object appeared on the screen and participants were asked to name it aloud. Responses were tape-recorded. This task was administered to each participant in one testing session.

The stimuli were presented in black on a white background via the software package PsyScope (Cohen et al., 1993). Stimulus items included: five high-frequency familiar objects (primes), fifteen low-frequency target objects semantically related to the primes, and five low-frequency control objects. The task began with a practice session where the 25 stimulus items were individually viewed on the computer screen and named by the examiner. The experimental task itself consisted of 240 trials, with a rest break after the first 122 items. The stimulus items were presented repeatedly in a fixed order. The distance between each prime picture and one of its three targets varied systematically. A target could appear immediately following, with two items between, or with four items between it and its prime. Only other prime pictures appeared between a target and its prime. Each of the five control objects appeared three times, once in each of the three possible distances from the prime pictures, in order to balance the presentation intervals between primes and targets in the list.

During the experimental task, the participant spoke into a tape-recorder with a built-in microphone positioned between the participant and the computer. A stimulus item appeared on the screen and remained there until the participant responded, for a maximum of five seconds. If the participant responded, upon the completion of the response, the examiner depressed any key on the PowerBook keyboard to trigger the offset of the picture on the screen. The next stimulus item appeared on the screen 500 ms later. If the participant did not respond within five seconds, the stimulus item was removed from the screen, and the next item appeared 500 ms later.

The task was designed in conjunction with the Language in the Aging Brain Laboratory to elicit perseveration in low-frequency target items by creating interference via earlier activation of the high-frequency lexical-semantic link. The distance between the prime and its target were examined to provide further information concerning the conditions under which perseveration occurs.

Scoring of Perseverations

Perseveration is being defined, following Sandson and Albert's (1984) definition of recurrent perseveration, as the unintentional repetition of a previously emitted response to a subsequent stimulus. For purposes of scoring, any response within a particular naming event was counted, even if that utterance was self-corrected. Perseverative responses were further categorized as to whether they were whole-word or part-word perseverations.

Santo Pietro and Rigrodsky (1982, 1986) categorize recurrent perseverations as either "total" or "blended" perseverations. A total perseveration is the intact repetition of a recently produced complete utterance. A blended perseveration is the partial repetition of an earlier utterance combined with an attempt at a new response. For purposes of both the Rapid Naming Task and Word Fluency, the definition of a whole-word perseveration is that of Santo Pietro and Rigrodsky's total perseveration. The definition of a part-word perseveration is an expansion of Santo Pietro and Rigrodsky's blended perseveration and, also, differs somewhat for each of our perseveration tasks, given the different nature of these two tasks.

On the Rapid Naming Task, the criteria for a part-word perseveration include either: (a) a blended perseveration - a partial repetition of an earlier utterance combined with an attempt at a new response; or (b) a partial utterance - a response consisting of at least two consecutive phonemes, but not all, of a preceding utterance. On Word Fluency, the criteria for a part-word perseveration include either: (a) a partial repetition of an earlier utterance combined with an attempt at a new response, resulting in a neologism; or (b) an utterance that would belong to a previous category. On this task, participants were instructed not to list "derivatives," that is derived forms, of words previously listed. Following Albert and Sandson's (1986) scoring guidelines, for consistency in scoring, all "derivatives" were considered incorrect but not perseverative.

All participants' responses on both tasks were scored by two independent raters, the primary author and a research assistant. Inter-rater reliability was quite high, and 99.7 percent of the time the judgment for each response was the same. The few instances of discrepant ratings were resolved through discussion.

Chapter 4

Results

Statistical Approach

The following analyses were conducted to test the specific hypotheses:

(1) Individuals with Wernicke's aphasia will evidence impaired inhibition in processing of lexical-semantic information relative to age-matched, normal controls. For the Stroop test, the reaction time and error percentage data were analyzed through a series of ANOVAs, post-hoc Newman-Keuls paired-group comparisons, and independent samples *t*-tests.

(2) Individuals with Wernicke's aphasia will evidence impaired inhibition but preserved activation of lexical-semantic information relative to age-matched, normal controls. For the List Priming Paradigm, the reaction time data were analyzed through a series of ANOVAs and post-hoc Newman-Keuls paired-group comparisons.

(3) The two operational measures of inhibition are tapping the same underlying processes. A Pearson Correlation analysis was performed on the factors of Stroop reaction time interference effect, Stroop error percentage interference effect, and LPP priming effects at 500 ms, 1100 ms, and 1500 ms.

(4) A behavioral manifestation of impaired inhibition is verbal perseveration. A Pearson Correlation analysis was performed on the factors of Rapid Naming task percentage of perseverations, Word Fluency test percentage of perseverations, Stroop

reaction time and error percentage interference effects, and LPP priming effects at 500 ms, 1100 ms, and 1500 ms.

(5) A behavioral manifestation of impaired inhibition is reduced auditory comprehension. A Pearson Correlation analysis was performed on the factors of Token Test score, Complex Ideational Material score, Stroop reaction time and error percentage interference effects, and LPP priming effects at the three ISIs.

Task 1 - The Stroop Test

The data for each participant were screened for mistrials and outliers. Mistrials were defined as responses greater than or equal to 5 seconds. Outliers were defined as responses greater than three standard deviations from the mean of all remaining responses for that participant.

The mean number of mistrials for the participants with Wernicke's aphasia was 5.5 out of a possible 216 trials, although Participant 5 evidenced 26 mistrials (2 in the compatible condition, 19 in the neutral condition, and 5 in the incompatible condition). Without Participant 5, the mean number of mistrials for the aphasic group was 1.4. The mean number of outliers for the participants with Wernicke's aphasia was 3.5, range 0 to 7. For the normal controls, the average number of mistrials was 0.75, and the average number of outliers was 3. The mean reaction time of correct responses (see Appendix F) and a percentage of incorrect responses (see Appendix G) were then calculated for each participant in each condition.

Reaction Time Data

The mean reaction times of the Wernicke's aphasic group and the control group, by condition, are displayed in Figure 1. A 2 (Group) x 3 (Condition) mixed factor ANOVA was conducted on the reaction time data (see Table 2). There was a reliable difference between the reaction times of the two groups, $p < .05$, and a reliable difference among the conditions, $p < .001$. Lending support to Hypothesis 1, the condition by group interaction was found to be significant, $p < .01$, indicating that the increase in response time across conditions was larger for the aphasics than for the controls.[5]

Table 2. Analysis of variance of all participants for Stroop reaction times.

Source	df	MS	*F*-ratio	Sig.
Group	1	2,167,639.600	5.806	.028*
S/G	16	373,328.250		
Condition	2	160,730.100	12.994	.000***
Condition x Group	2	87,078.388	7.040	.003**
Condition x S/G	32	12, 369.278		

Referring to Appendix F, we see that the reaction times of Participant 5 are considerably slower than those of the other subjects, although they are within 2 standard deviations of the aphasic mean for the compatible and neutral conditions and 2.5 standard

[5] There was no reason to suspect a difference in performance based on gender in the control group. Nevertheless, given that all the participants with aphasia were male and half of the control group was female, analyses were run to rule out this possibility. A 2 (Group) x 3 (Condition) mixed factor ANOVA revealed no significant differences in response times for the male and female control groups, $F(1,10) < 1$, n.s. In addition, the facilitation and interference effects evidenced by these two groups were virtually the same.

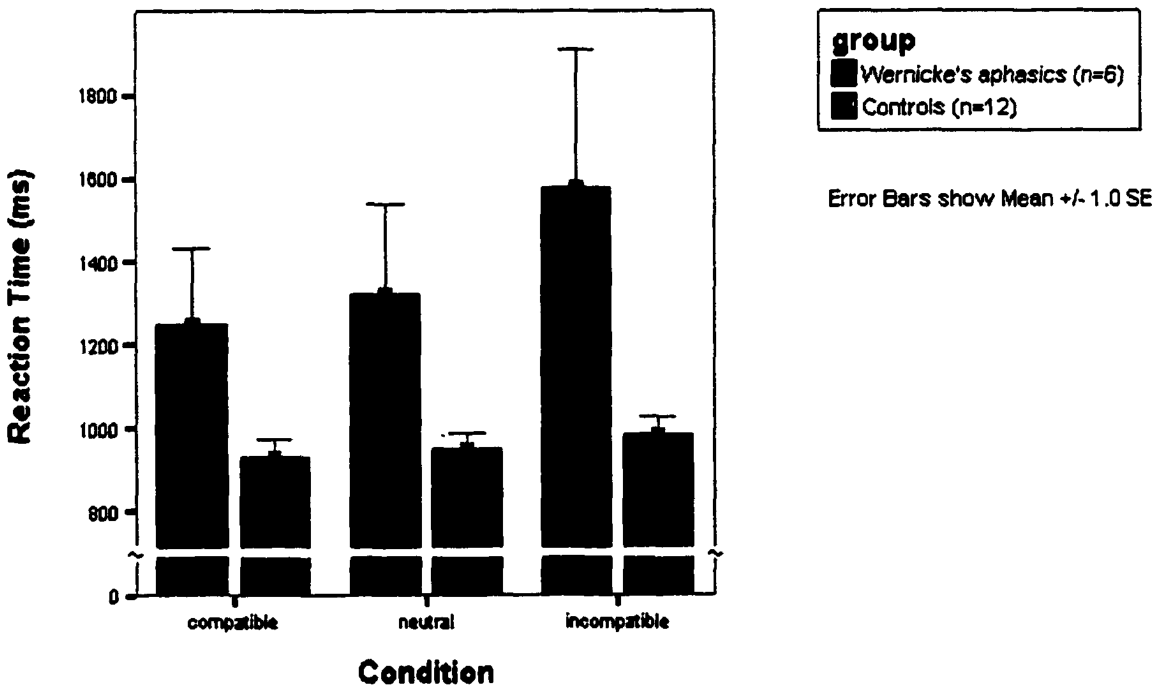


Figure 1. Stroop mean reaction times for the Wernicke's aphasic group and the normal control group, by condition.

deviations of the aphasic mean for the incompatible condition. In addition, as seen in Appendix G, the percentage of errors in the incompatible condition for Participant 5 is large, contributing to a small number of correct responses (n= 7) that can be analyzed for reaction time in that condition. Therefore, the data also were analyzed excluding Participant 5.[6]

The mean reaction times of the two experimental groups, excluding Participant 5, by condition, are displayed in Figure 2. A 2 x 3 mixed factor ANOVA was conducted on the reaction time data (see Table 3). There was a reliable difference between the reaction times of the two groups, $p < .05$, and a reliable difference among the conditions, $p < .001$. The condition by group interaction was found to be significant, $p < .001$, indicating once again that the increase in response time across conditions was larger for the participants with Wernicke's aphasia than for the controls.

To decompose the condition by group interaction, simple effects tests were conducted within each subject group. An ANOVA table for the participants with Wernicke's aphasia, the aphasic participants excluding Participant 5, and the normal controls can be found in Tables 4, 5, and 6, respectively. As shown in Table 4, there was

---

[6] As to what might account for this outlier performance of Participant 5, referring to Table 1, we see he does not stand out on any demographic feature except that his aphasia is one of the most severe. As shown in Appendix J, his scores on the two measures of auditory comprehension are the most severely impaired in the group. The other measure examined was lesion location. Reports of his initial MRI revealed a left parietal lesion, along with subcortical lesions; however, further information concerning the size and more specific location of these lesions is unavailable. While only one other participant had subcortical involvement in addition to a left cortical lesion, that was Participant 3, one of the least severely impaired participants. Moreover, Participant 3 was one of the fastest respondents of the participants with aphasia on the Stroop test and demonstrated relatively low error percentages. Therefore, subcortical extension alone cannot explain Participant 5's outlier status. Given the difficulties in comparing lesion data from somewhat limited available reports, we cannot draw many conclusions concerning the relationship between lesion data and specifics in performance on our measures. However, it appears likely that Participant 5's outlier performance on the Stroop test is related to the severity of his aphasia and, most particularly, to the severity of his auditory comprehension deficits.

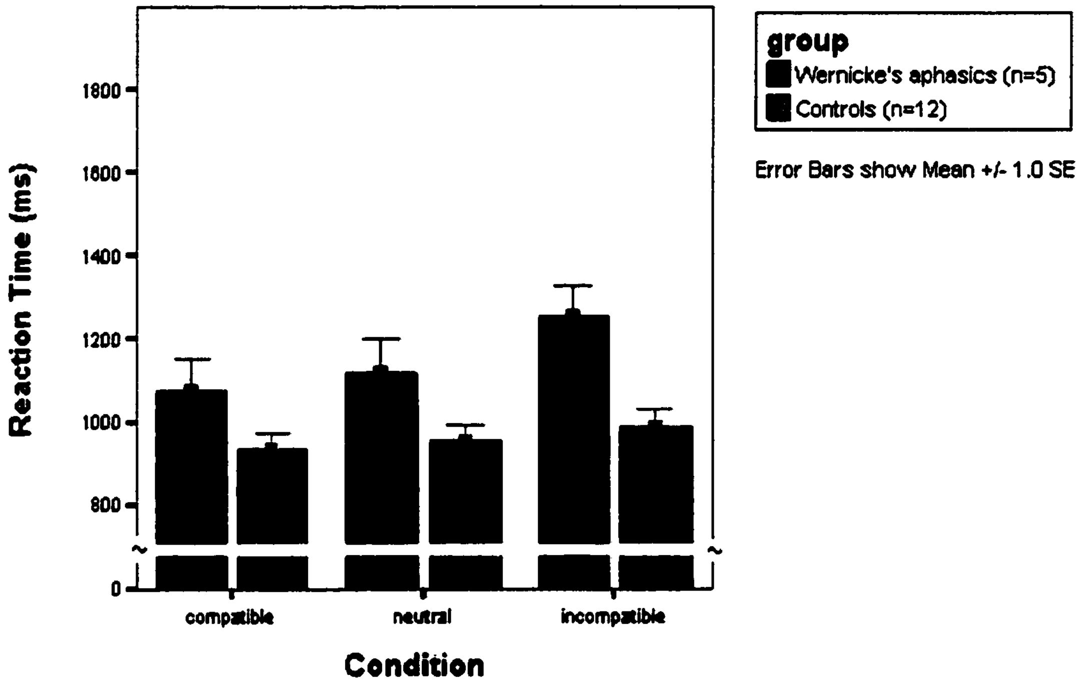


Figure 2. Stroop mean reaction times for the Wernicke's aphasic group, excluding Participant 5, and the normal control group, by condition.

Table 3. Analysis of variance of all participants, excluding Participant 5, for Stroop reaction times.

Source	df	MS	*F*-ratio	Sig.
Group	1	383,496.330	5.664	.031*
S/G	15	67,710.772		
Condition	2	51,785.773	88.852	.000***
Condition x Group	2	16,391.488	28.124	.000***
Condition x S/G	30	582.831		

Table 4. Analysis of variance of all participants with Wernicke's aphasia for Stroop reaction times.

Source	df	MS	*F*-ratio	Sig.
Subject	5	1,060,617.600		
Condition	2	181,560.57	4.652	.037*
Condition x S	10	39,026.796		

---

a reliable difference among the conditions for the participants with Wernicke's aphasia, $p < .05$. Table 5 reveals that the conditions remain reliably different among the aphasic participants when Participant 5 is excluded, $p < .001$. Table 6 reveals a significant difference among the conditions for the control participants, $p < .001$.

Table 5. Analysis of variance of participants with Wernicke's aphasia, excluding Participant 5, for Stroop reaction times.

Source	df	MS	*F*-ratio	Sig.
Subject	4	86,374.391		
Condition	2	44,712.391	29.968	.000***
Condition x S	8	1,491.999		

Table 6. Analysis of variance of control participants for Stroop reaction times.

Source	df	MS	*F*-ratio	Sig.
Subject	11	60,924.001		
Condition	2	8,591.606	34.063	.000***
Condition x S	22	252.224		

Post-hoc Newman-Keuls paired-group comparisons then were performed for each subject group. For each group, three paired comparisons were made: (1) the difference between the neutral and compatible conditions (the facilitation effect); (2) the difference between the incompatible and the neutral conditions (the interference effect); and (3) the difference between the facilitation effect and the interference effect. The results for all groups are summarized in Table 7. We can see that, while the facilitation effect was not

---

Table 7. Post-hoc Newman-Keuls paired-group comparisons for Stroop reaction times for participants with Wernicke's aphasia, aphasic participants excluding Participant 5, and normal controls.

Group	Comparisons	*t*	df	2-tailed probability
Aphasics:	Facilitation	0.93	10	n.s.
	Interference	3.18	10	$p < .05$*
	Facilitation - Interference	4.11	10	$p < .05$*
Aphasics, excluding Participant 5:	Facilitation	2.50	8	n.s.
	Interference	7.99	8	$p < .001$***
	Facilitation - Interference	10.48	8	$p < .001$***
Normal controls:	Facilitation	4.18	22	$p < .01$**
	Interference	7.36	22	$p < .001$***
	Facilitation - Interference	11.54	22	$p < .001$***

significant for the participants with Wernicke's aphasia, the interference effect was significant, $p < .05$, and the difference between the facilitation effect and the interference effect was significant, $p < .05$. The results are similar when Participant 5 is excluded from the aphasic group; the facilitation effect is not significant, but the interference effect and the difference between the facilitation effect and the interference effect are both significant at $p < .001$. In the normal control group, the facilitation effect is significant, $p < .01$, and both the interference effect and the difference between the facilitation effect and the interference effect are significant at $p < .001$.

The final step in the analysis of the Stroop reaction time data involved a comparison across groups, between the normal controls and the participants with Wernicke's aphasia and between the normal controls and the aphasic group excluding Participant 5. Three 2 (Group) x 2 (Condition) mixed factor ANOVAs were conducted for each of these comparisons, comparing: (1) the difference between the neutral and compatible conditions; (2) the difference between the incompatible and the neutral conditions; and (3) the difference between the neutral condition minus the compatible condition and the incompatible condition minus the neutral condition.

As shown in Table 8, when we compare the neutral and compatible conditions in the control group to those in the entire aphasic group, there is a reliable difference between the two groups, $p < .05$, and a reliable difference across the conditions, $p < .01$. The condition by group interaction was found to be significant, $p < .05$. As seen in Table 9, when comparing the incompatible and neutral conditions, there is a reliable difference between the two groups, $p < .05$, and across the two conditions, $p < .01$, and the

Table 8. Analysis of variance of all participants for the difference between Stroop reaction times in the neutral and compatible conditions.

Source	df	MS	*F*-ratio	Sig.
Group	1	932,226.080	5.271	.036*
S/G	16	176,857.000		
Condition	1	17,677.574	14.552	.002**
Condition x Group	1	6,215.711	5.117	.038*
Condition x S/G	16	1,214.813		

Table 9. Analysis of variance of all participants for the difference between Stroop reaction times in the incompatible and neutral conditions.

Source	df	MS	*F*-ratio	Sig.
Group	1	1,849,167.400	6.035	.026*
S/G	16	306,408.100		
Condition	1	168,792.950	11.880	.003**
Condition x Group	1	99,529.288	7.005	.018*
Condition x S/G	16	14,208.065		

---

condition by group interaction is significant, $p < .05$. As shown in Table 10, when comparing the differences between the neutral condition minus the compatible condition and the incompatible minus the neutral condition, there is a reliable difference between the two groups, $p < .05$, across the conditions, $p = .01$, and the condition by group interaction is significant, $p < .05$.

Comparing these findings with the direction of effects displayed in Figure 1, while there appears to be a tendency for the participants with Wernicke's aphasia to evidence a facilitation effect, the variability within this group prevents this effect from being reliable.

Table 10. Analysis of variance of all participants for the difference between Stroop reaction times in the neutral minus compatible condition and the incompatible minus the neutral condition.

Source	df	MS	*F*-ratio	Sig.
Group	1	155,490.160	7.170	.017*
S/G	16	21,684.957		
Condition	1	77,221.272	8.430	.010**
Condition x Group	1	55,999.835	6.113	.025*
Condition x S/G	16	9,160.798		

In contrast, for the normal controls, there is a reliable facilitation effect. In addition, although both groups demonstrate an interference effect, it is significantly larger in the participants with Wernicke's aphasia than in the normal control group, supporting Hypothesis 1.

These same analyses were conducted comparing the control group with the aphasic group excluding Participant 5. As shown in Table 11, when comparing the neutral and compatible conditions, there is a marginal difference between the groups, p = .076, a reliable difference across the conditions, $p < .001$, and a marginal condition by group interaction, $p = .080$.

Table 11. Analysis of variance of all participants, excluding Participant 5, for the difference between Stroop reaction times in the neutral and compatible conditions.

Source	df	MS	*F*-ratio	Sig.
Group	1	162,190.620	3.638	.076
S/G	15	44,580.643		
Condition	1	6,839.675	23.817	.000***
Condition x Group	1	1,015.571	3.536	.080
Condition x S/G	15	287.181		

As shown in Table 12, when comparing the incompatible and neutral conditions, there is a reliable difference between the two groups, $p < .05$, across the two conditions, $p < .001$, and the condition by group interaction is significant, $p < .01$.

Table 12. Analysis of variance of all participants, excluding Participant 5, for the difference between Stroop reaction times in the incompatible and neutral conditions.

Source	df	MS	*F*-ratio	Sig.
Group	1	328,349.930	6.035	.017*
S/G	15	45,722.958		
Condition	1	51,983.029	11.880	.000***
Condition x Group	1	19,160.450	7.005	.001**
Condition x S/G	15	1,022.778		

As presented in Table 13, when comparing the differences between the neutral condition minus the compatible condition and the incompatible minus the neutral condition, there is a reliable difference between the two groups, $p < .001$, across the conditions, $p = .01$, and the condition by group interaction is significant, $p < .05$.

Table 13. Analysis of variance of all participants, excluding Participant 5, for the difference between Stroop reaction times in the neutral minus compatible condition and the incompatible minus the neutral condition.

Source	df	MS	*F*-ratio	Sig.
Group	1	28,998.444	66.126	.000***
S/G	15	438.534		
Condition	1	21,110.795	9.678	.007**
Condition x Group	1	11,353.597	5.205	.038*
Condition x S/G	15	2,181.383		

Comparing these findings with the direction of effects displayed in Figure 2, we can conclude that the facilitation effect is not significantly larger in the aphasic group, excluding Participant 5, than in the control group, but that the interference effect is significantly larger in this aphasic group compared with the controls, continuing to support Hypothesis 1.

Error Percentage Data

The mean error percentages of the Wernicke's aphasic group and the control group, by condition, are displayed in Figure 3. As most participants made no errors in the compatible and neutral conditions, and error rate was very low in these conditions, a single sample *t*-test was conducted for each group comparing the percentage of errors in the incompatible condition with a known population mean, zero. The *t*-value for the aphasic group was not significant, although the *t*-value for the control group was significant at $p < .01$.

Given the large percentage of errors evidenced by Participant 5 in the incompatible condition (see Appendix G), the data then were analyzed excluding this subject. The mean error percentages of the two experimental groups, excluding Participant 5, are displayed in Figure 4. The *t*-value for this aphasic group was significant at $p = .05$.

An independent samples *t*-test was then conducted comparing the error percentage interference effect demonstrated by the aphasic group, excluding Participant 5, to that of the control group. The difference was reliable at $p < .05$.

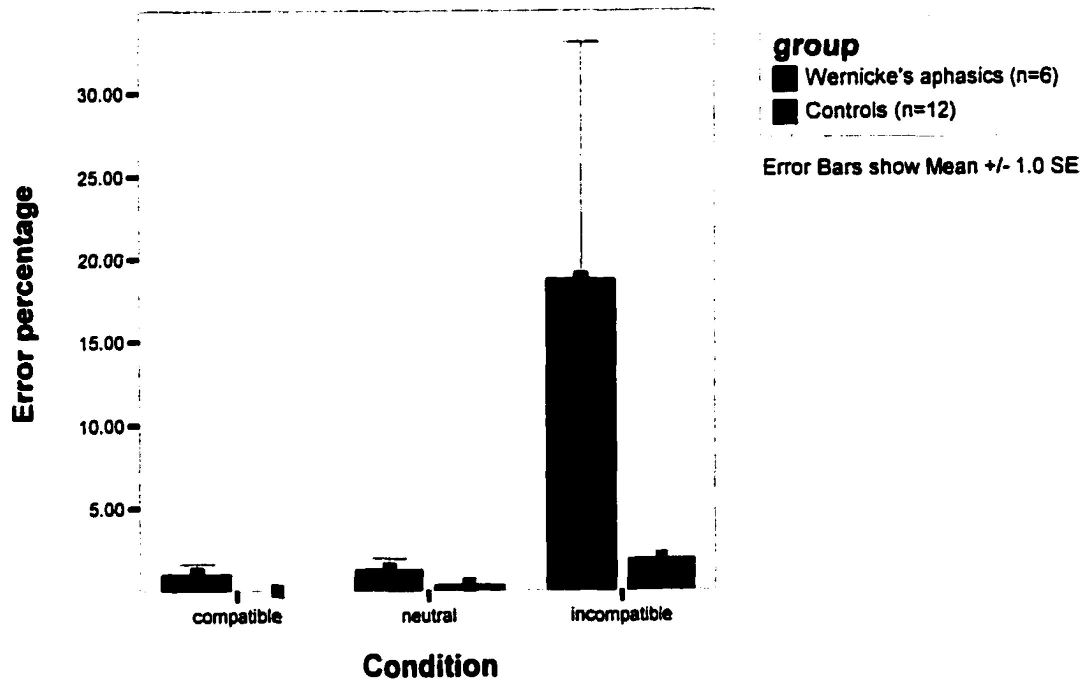


Figure 3. Stroop mean error percentages for the Wernicke's aphasic group and the normal control group, by condition.

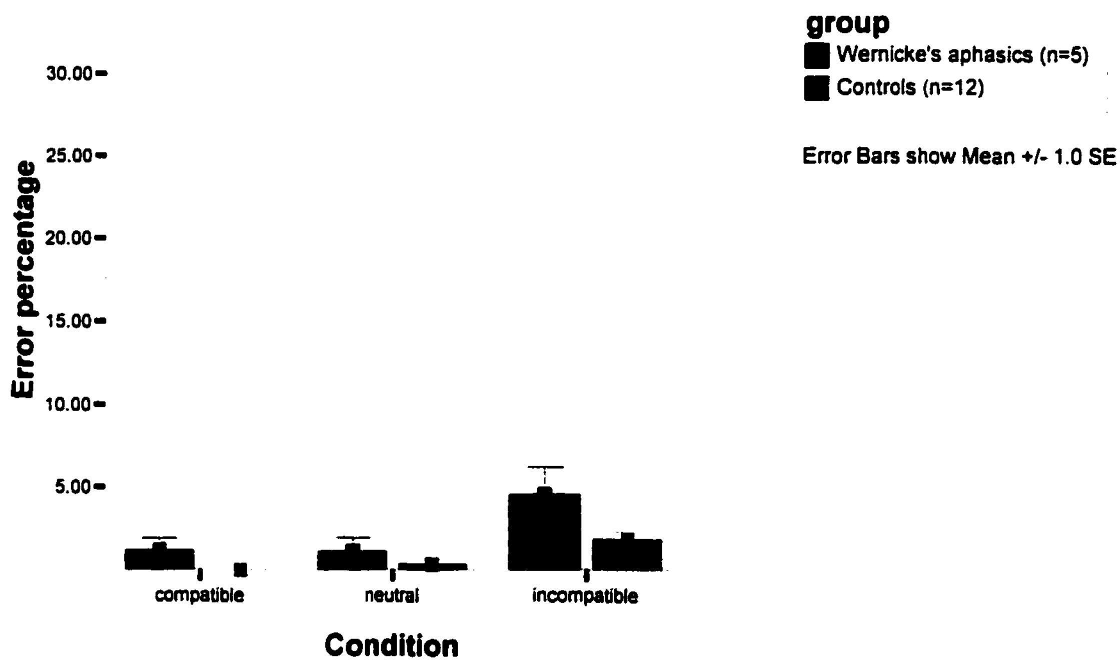


Figure 4. Stroop mean error percentages for the Wernicke's aphasic group, excluding Participant 5, and the normal control group, by condition.

To summarize, we can draw two major conclusions from the analysis of the Stroop error percentage data. First, the low error rates for the participants with Wernicke's aphasia (apart from Participant 5's large error rate in the incompatible condition) indicate that these subjects were successful in performing the task and confirm that the reaction time data are not a result of a speed-accuracy trade-off. Second, the error percentage data are consistent with the reaction time data, whereby the interference effect is disproportionately larger than the facilitation effect in the aphasic group as compared to the control group. Thus, Hypothesis 1 is further supported.

Task 2 - List Priming Paradigm

The data for each participant were screened for errors. If an error occurred in either the related or control condition of a target word, that target word was excluded from the data analysis. The data also were screened for outliers, defined as reaction times more than three standard deviations above or below the participant's mean reaction time. The mean reaction times for each participant in the related and control conditions, sorted by ISI, were calculated (see Appendix H).

The error rates in this task for both groups of participants were quite low and distributed across the ISIs. The screened reaction time data for the target words for the aphasic group represents 91% of the total data at each ISI of 500 ms, 1100 ms, and 1500 ms. For the control group, the screened data represents 94% of the total data at the ISIs of 500 and 1100 ms and 97% of the total data at the ISI of 1500 ms.

The mean reaction times of the aphasic group and the normal control group in the related and control conditions at each ISI are displayed in Figure 5. A mixed factorial ANOVA design was utilized, with the factor Group as a between-subjects factor, and the factors prime-target Relatedness and Inter-Stimulus Interval (ISI) as within-subject factors (see Table 14). There was a reliable difference between the reaction times of the two experimental groups, $p < .01$. While there was a significant main effect of relatedness ($p < .001$), the relatedness by group interaction was only marginally significant at $p = .072$. Similarly, while there was a significant main effect of ISI ($p < .05$), the ISI by group interaction was only marginally significant at $p = .067$. The relatedness by ISI interaction

---

Table 14. Analysis of variance of all participants for List Priming Paradigm reaction times.

Source	df	MS	*F*-ratio	Sig.
Group	1	1,298,215.300	14.529	.002**
S/G	16	89,356.042		
Relatedness	1	21,900.730	20.192	.000***
Rel x Group	1	4,027.753	3.714	.072
Rel x S/G	16	1084.617		
ISI	2	10,323.033	4.175	.024*
ISI x Group	2	7,296.093	2.951	.067
ISI x S/G	32	2,472.578		
Relatedness x ISI	2	2,060.115	3.647	.037*
Rel x ISI x Group	2	1,070.529	1.895	.167
Rel x ISI x S/G	32	564.883		

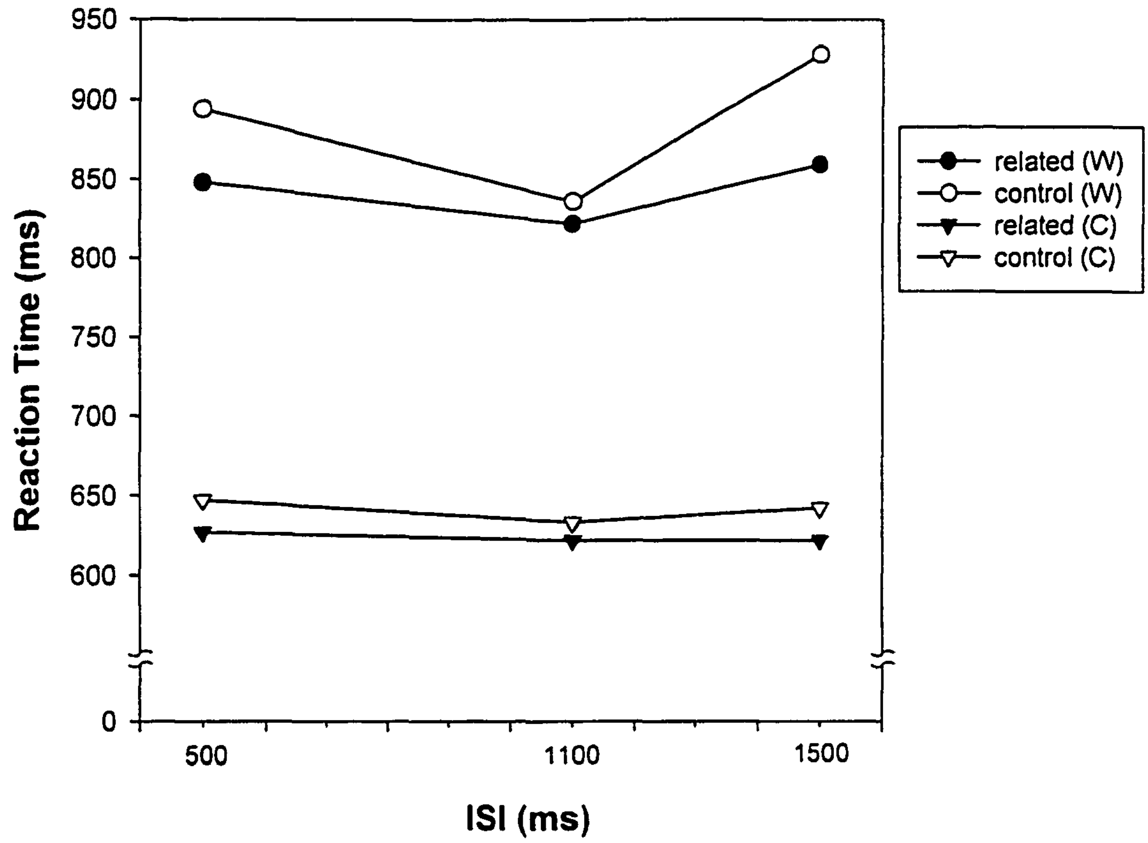


Figure 5. List Priming Paradigm mean reaction times for the Wernicke's aphasic group (W) and the normal control group (C) in the related and control conditions at each ISI.

was significant, $p < .05$, although the relatedness by ISI by group interaction was not found to be significant.[7] [8] [9]

The next stage of analysis involved a within-subject 2 (Relatedness) x 3 (ISI) ANOVA conducted for each of the two subject groups. As seen in Table 15, there was a reliable difference for the factor of relatedness for the participants with Wernicke's aphasia, $p < .05$, such that related items were responded to more quickly than the control items; however, neither ISI nor the interaction between relatedness and ISI was found to be significant.

Table 15. Analysis of variance of all participants with Wernicke's aphasia for List Priming Paradigm reaction times.

Source	df	MS	*F*-ratio	Sig.
Subject	5	178,291.610		
Relatedness	1	16,767.223	7.284	.043*
Rel x S	5	2,301.904		
ISI	2	12,938.110	2.134	.169
ISI x S	10	6,061.801		
Relatedness x ISI	2	2,277.827	1.859	.206
Rel x ISI x S	10	1,225.180		

---

[7] Given Participant 5's outlier performance difference on the Stroop Test, the List Priming Paradigm (LPP) data were analyzed both including and excluding Participant 5; however, there was no difference in the pattern of priming results.

[8] The LPP data also were analyzed for differences between day 1 and day 2 performance. While there was a marginally significant main effect, such that average reaction times were faster on day 2 than on day 1, there were no interactions with day; therefore, the data were collapsed across days.

[9] Possible differences in performance within the control group based on gender were also analyzed. A 2 (Group) x 2 (Relatedness) x 3 (ISI) mixed factor ANOVA revealed no significant differences in response times for the male and female control groups, $F(1,10) < 1$, n.s. In addition, as found with the Stroop data, the pattern of performance was similar for these two groups.

As shown in Table 16, there was a reliable difference for the factor of relatedness for the normal controls, $p < .01$, although neither ISI nor the interaction between relatedness and ISI was significant, as similarly found with the participants with aphasia.

Table 16. Analysis of variance of control participants for List Priming Paradigm reaction times.

Source	df	MS	*F*-ratio	Sig.
Subject	11	48,930.785		
Relatedness	1	5,358.277	10.085	.009**
Rel x S	11	531.304		
ISI	2	552.469	.657	.528
ISI x S	22	841.112		
Relatedness x ISI	2	140.312	.530	.596
Rel x ISI x S	22	264.748		

Post-hoc Newman-Keuls paired-group comparisons then were performed for each of the two experimental groups. For each group, three paired comparisons were made: (1) the difference between the related condition and the control condition at an ISI of 500 ms; (2) the difference between the related and control conditions at an ISI of 1100 ms; and (3) the difference between the related and control conditions at an ISI of 1500 ms. The results for the two subject groups are summarized in Table 17. We see that, for the participants with Wernicke's aphasia, there was a reliable priming effect at an ISI of 500 ms, $p < .05$, and at 1500 ms, $p < .01$, although the difference between the related and control conditions at an ISI of 1100 ms was not significant. Similarly, for the control subjects, there was a reliable priming effect at an ISI of 500 ms, $p < .01$, and at 1500 ms, $p < .01$, although reliable priming was not evidenced at an ISI of 1100 ms.

Table 17. Post-hoc Newman-Keuls paired-group comparisons for List Priming Paradigm reaction times for participants with Wernicke's aphasia and normal controls.

Group	Comparisons by ISI	*t*	df	2-tailed probability
Aphasics:	500 ms - related vs. control	3.21	10	$p < .05$*
	1100 ms - related vs. control	1.00	10	n.s.
	1500 ms - related vs. control	4.84	10	$p < .01$**
Normal controls:	500 ms - related vs. control	4.21	22	$p < .01$**
	1100 ms - related vs. control	2.49	22	n.s.
	1500 ms - related vs. control	4.32	22	$p < .01$**

In summary, while the average response times of the participants with Wernicke's aphasia were found to be significantly longer than those of the normal controls, the two groups demonstrated a similar priming pattern, whereby reliable priming was evidenced at ISIs of 500 ms and 1500 ms, but not at an ISI of 1100 ms. Thus, Hypothesis 2 was not supported.

Measures of Verbal Perseveration

The total number of whole-word and part-word perseverations was tabulated for each participant on the Rapid Naming task. Naming response attempts were counted, and a percentage of each subject's degree of overall perseveration (the sum of whole- and part-word perseverations) on the task was calculated. Similarly, on the Word Fluency test, the total number of whole-word and part-word perseverations was tabulated for each participant, along with the number of total responses in 4.5 minutes (ninety seconds for each of the letters "F," "A," and "S"). A percentage of overall perseveration was calculated for this task. The results for all participants are summarized in Appendix I.

On the Rapid Naming task, the participants with Wernicke's aphasia produced an average of 22.5 perseverations in a mean corpus of 253.7 naming response attempts, resulting in 8.8 percentage of their utterances being perseverations. In contrast, the normal controls produced an average of 1.3 perseverations in a mean corpus of 242.3 naming response attempts, resulting in 0.5 percent perseveration.

On the Word Fluency test, the participants with Wernicke's aphasia produced an average of only 2.7 perseverations, although their mean number of total responses on this test was very low at 15.2. Thus, 17.7 percent of this group's utterances were perseverations. The normal controls produced an average of 4.0 perseverations in a mean corpus of 64.3 responses, resulting in 5.8 percent of their utterances being perseverations.

Measures of Auditory Comprehension

The raw scores on the Token Test and on the Complex Ideational Material subtest of the *BDAE* were tabulated for each participant and converted to correct accuracy percentages. These raw scores and percentages, along with the degree of severity of impairment represented by these scores for the participants with Wernicke's aphasia, are shown in Appendix J.

The participants with Wernicke's aphasia obtained raw scores on the Token Test ranging from 62 to 104 out of a possible 163 correct, reflecting severe to moderate-severe deficits when plotted on the *NCCEA* aphasia profile. Their raw scores on the Complex Ideational Material subtest ranged from 4 to 9/12 correct, reflecting severe to mild deficits when plotted on the *BDAE* aphasia summary profile. The normal controls demonstrated only minimal reductions on these two tests, reflected by a mean score of 161/163 on the Token Test and 11.2/12 on the Complex Ideational Material subtest.

Cross-Measures Comparisons

In order to investigate the relationship between the Stroop interference effect and the priming effects for each subject group and to increase our understanding of how active or passive the deactivational mechanism in priming might be, a Pearson Correlation analysis was performed. To support Hypothesis 3, we would expect a significant positive correlation between the interference effect on the Stroop test and the LPP priming effects.

In addition, in order to examine factors that may predict Stroop interference performance and priming effects, demographic factors of age, education, and time post-onset, and the clinical-behavioral measures of verbal perseveration and auditory comprehension were included in the Pearson Correlation analysis. To support Hypothesis 4, a significant positive correlation would be found with the measures of inhibition and the frequency of verbal perseveration. To support Hypothesis 5, we would expect a significant positive correlation with the measures of inhibition and the severity of auditory comprehension.

Given the relatively small number of aphasic subjects who participated in this study, the correlational analyses were viewed as exploratory in nature. In addition, as one could obtain spuriously high correlations by including Participant 5 in the aphasic group, due to his extremely high scores in both Stroop error percentage and reaction time data, he was omitted from these analyses. Table 18 summarizes the correlations for the aphasic group excluding Participant 5.

By first examining the correlations between the dependent measures, we see that the Stroop error percentage interference effect is negatively correlated with greater LPP priming at 1500 ms ($p < .05$). As a significant positive correlation between these two measures was not evidenced at an ISI of either 500 ms or 1100 ms, and the correlation was a negative one at an ISI of 1500 ms, Hypothesis 3 is not supported.

By next examining the correlations between demographic factors and Stroop and priming performance, we find that priming at 1500 ms is negatively correlated with a higher level of formal education ($p < .05$). Priming at 500 ms is marginally positively correlated with greater chronological age ($p = .052$).

We can then examine the correlations between the clinical-behavioral measures and Stroop and priming performance. We see that the Stroop error percentage interference effect is negatively correlated with a higher Token Test score ($p < .05$), supporting the hypothesis that the severity of auditory comprehension deficits will be positively correlated with impaired Stroop inhibition. However, as priming at 1500 ms is

Table 18. **Pearson Correlation analysis for the aphasic group excluding Participant 5 for factors of: Stroop reaction time interference effect (S-RT); Stroop error percentage interference effect (S-ERR); LPP priming effect at 500 ms (P-500), 1100 ms (P-1100), and 1500 ms (P-1500); age; education (educ); time post-onset in months (t-po); Rapid Naming task percentage of perseveration (RNT); Word Fluency test percentage of perseveration (WF); Token Test score (TT); and Complex Ideational Material score (CIM).**

	S-ERR	**P-500**	**P-1100**	**P-1500**	**age**	**educ**	**t-po**	**RNT**	**WF**	**TT**	**CIM**
S-RT	.162	-.270	.741	-.551	.068	.467	.634	-.326	.208	-.379	.769
S-ERR	-	-.532	.107	**-.879***	-.248	.745	.210	-.102	-.752	**-.911***	-.069
P-500	-	-	-.501	.660	**.876+**	-.748	.088	.596	.565	.337	-.594
P-1100	-	-	-	-.556	-.440	.717	.699	**-.872+**	-.216	-.322	.697
P-1500	-	-	-	-	.352	**-.934***	-.510	.442	.656	**.913***	-.316
age	-	-	-	-	-	-.586	.188	.730	.610	.052	-.392
educ	-	-	-	-	-	-	.537	-.721	-.762	-.793	.353
t-po	-	-	-	-	-	-	-	-.483	-.182	-.587	.133
RNT	-	-	-	-	-	-	-	-	.502	.215	-.458
WF	-	-	-	-	-	-	-	-	-	.667	.239
TT	-	-	-	-	-	-	-	-	-	-	.054
CIM	-	-	-	-	-	-	-	-	-	-	-

***Correlation is significant at the 0.05 level (2-tailed).**

+Correlation is marginally significant at the 0.10 level (2-tailed).

positively correlated with a higher Token Test score ($p < .05$), and a significant negative correlation between these two measures was not evidenced at an ISI of either 500 ms or 1100 ms, the hypothesis that the severity of auditory comprehension deficits will be positively correlated with delayed deactivation of priming is not supported.

Regarding Hypothesis 4, we find that greater perseveration on the Rapid Naming task is only marginally negatively correlated with priming at 1100 ms ($p = .054$). Thus, the hypothesis that frequency of verbal perseveration will be positively correlated with impaired Stroop inhibition and delayed deactivation of priming is not supported.

Finally, the same correlational analyses, excluding the factor of time post-onset, were conducted for the control group (see Table 19). Although predictions were not hypothesized for these analyses, these findings may add to our understanding of the relations found amongst the participants with aphasia. We see that LPP priming at 500 ms is positively correlated with priming at 1500 ms ($p < .05$). Greater chronological age is negatively correlated with a higher Token Test score ($p < .05$). A higher level of formal education is marginally positively correlated with a greater degree of perseveration on the Word Fluency test ($p = .072$).

Table 19. Pearson Correlation analysis for the normal control group for factors of: Stroop reaction time interference effect (S-RT); Stroop error percentage interference effect (S-ERR); LPP priming effect at 500 ms (P-500), 1100 ms (P-1100), and 1500 ms (P-1500); age; education (educ); Rapid Naming task percentage of perseveration (RNT); Word Fluency test percentage of perseveration (WF); Token Test score (TT); and Complex Ideational Material score (CIM).

	S-ERR	P-500	P-1100	P-1500	age	educ	RNT	WF	TT	CIM
S-RT	.334	.088	.328	.335	-.085	-.087	-.086	-.009	.115	-.092
S-ERR	-	-.118	.106	.340	.225	-.125	.135	-.220	.001	.227
P-500	-	-	-.083	**.606***	-.107	.199	-.450	.194	.430	.027
P-1100	-	-	-	.121	-.033	.222	-.178	.018	-.326	-.283
P-1500	-	-	-	-	-246	.389	-.175	.006	.312	.025
age	-	-	-	-	-	-.476	-.353	-.087	**-.583***	.090
educ	-	-	-	-	-	-	.423	**.537+**	.371	-.426
RNT	-	-	-	-	-	-	-	.096	.000	-.293
WF	-	-	-	-	-	-	-	-	.380	-.351
TT	-	-	-	-	-	-	-	-	-	.092
CIM	-	-	-	-	-	-	-	-	-	-

*Correlation is significant at the 0.05 level (2-tailed).
+Correlation is marginally significant at the 0.10 level (2-tailed).

Chapter 5

Discussion

The goal of this study was to investigate the extent to which inhibition is impaired in Wernicke's aphasia at the lexical-semantic level of language processing. The first part of the study examined whether inhibition in controlled processing of lexical-semantic information is impaired in Wernicke's aphasia and whether this impairment is due to the aphasia type or the impact of age. The one study in the aphasia literature (Milberg et al., 1995) that compared automatic and controlled processing of lexical-semantic information in Wernicke's aphasia utilizing on-line methods revealed reduced inhibitory function relative to the Broca's aphasics and the young normal control group; however, the participants with Wernicke's aphasia performed similarly to the age-matched old normal control group. Thus, it remained unclear whether this reduction in inhibitory function was due to the aphasia type or the older age associated with Wernicke's aphasia.

Task 1 - The Stroop Test

Task 1 of this study involved administration of an adapted computerized, manual-response, numerical version of the Stroop test to individuals with Wernicke's aphasia and age- and education-matched normal controls. It was hypothesized that the participants with Wernicke's aphasia would show greater difficulty than the control subjects in inhibiting the automatically activated word information represented by the Arabic numeral when attempting to respond to the quantity of items. Impaired inhibition was defined as a significantly greater interference effect, without a significant increase in the facilitation effect when compared with the control subjects.

Reaction time analyses indicated that the facilitation effect was significantly larger in the normal control group than in the Wernicke's aphasic group, while the interference effect was significantly larger for the participants with Wernicke's aphasia than for the controls. While Hypothesis 1 did not predict a larger facilitation effect in the control group, the prediction of a disproportionately larger interference effect with Wernicke's aphasia was confirmed, supporting an impairment in inhibition in controlled processing of lexical-semantic information in Wernicke's aphasia. That is, the participants with Wernicke's aphasia demonstrated greater difficulty than the control subjects in inhibiting an automatic response.

A question remains as to why there was a reliable facilitation effect for the normal control group and not for the participants with Wernicke's aphasia. In MacLeod's (1991) extensive review of the Stroop phenomenon, he concludes that, while the congruent condition often produces facilitation, this facilitation is less than the corresponding interference in the incongruent condition. The facilitation effect is subtle and easily affected by small changes in stimulus items. In fact, Salthouse and Meinz (1995) did not find significant facilitation effects in the normal adult population they tested with their numerical version of the Stroop test upon which Task 1 was based. In the present study, the Wernicke's aphasic group was smaller in number than the control group and demonstrated greater variability in performance than did the control subjects. Thus, it appears likely that the lack of a facilitation effect among the participants with Wernicke's aphasia was related to these issues of power and variability, particularly given that a tendency towards facilitation was demonstrated by the aphasic group.

In order to confirm the validity of the Stroop reaction time results, to assure they were not the result of a speed-accuracy trade-off and that this task was, in fact, appropriate for individuals with Wernicke's aphasia, the error percentage data were analyzed. While one participant with Wernicke's aphasia, Participant 5, demonstrated an extremely high error rate in the incompatible condition, error rates were, otherwise, quite low for the group, and virtually absent in the compatible (less than 1 percent) and neutral (less than 1.3 percent) conditions. Analyses of the error rates of the aphasic group, excluding Participant 5, as compared with the control group in the incompatible condition revealed significantly greater interference in the aphasic group. Thus, the error percentage data further supported Hypothesis 1, whereby the interference effect was larger in the aphasic group than in the control group, without an accompanying increase in facilitation, reflecting an impairment in inhibition.

Task 2 - List Priming Paradigm

The second experimental task of the study involved a further look at the relationship between inhibition and activation in Wernicke's aphasia. While the aphasia literature has revealed relatively preserved automatic activation in Wernicke's aphasia, Prather et al. (1997), employing somewhat different methodology, revealed a possible abnormality in the priming pattern associated with Wernicke's aphasia. Utilizing a list priming paradigm (LPP), rather than the traditional pair priming paradigm, not only could they maximize the likelihood that priming performance was restricted to automatic effects, but the interstimulus interval (ISI) could be varied between each letter string to determine the longest and shortest intervals at which priming occurs. In contrast to their participants with Broca's aphasia who evidenced slowed lexical activation, their participant with Wernicke's aphasia (JM) obtained a priming effect as early as the normal controls, at an ISI of 300 ms, revealing preserved activation. However, while loss of priming was evidenced within 300 ms of obtaining priming in both the normal controls and the participants with Broca's aphasia, JM continued to show significant priming effects at an ISI of 1100 ms, with loss of priming not evidenced until an ISI of 1500 ms. That is, priming based upon automatic spreading-activation persisted for at least 800 ms after it was initially observed.

Task 2 of this study involved administration of the Prather et al. paradigm to a larger subject pool, the same individuals who participated in Task 1, to further study the deactivation component of automatic lexical activation in Wernicke's aphasia and normal age- and education-matched controls. As the error rates for this task were quite low for both groups of participants and distributed across the ISIs, the screened reaction time data served as a good representation of the subjects' performance. Results indicated that, although the average response times of the participants with Wernicke's aphasia were significantly longer than those of the normal controls, the two groups demonstrated a similar priming pattern. Reliable priming was evidenced at the shortest ISI tested (500 ms) in both groups, and, in each group, a loss of priming was evidenced by the next ISI tested (1100 ms). Furthermore, priming was significant for both groups at the last and longest ISI tested (1500 ms). Thus, as delayed deactivation of priming was not demonstrated by the participants with Wernicke's aphasia at the ISI of 1100 ms as predicted, Hypothesis 2 was not supported. That is, in the automatic processing realm, the participants with Wernicke's aphasia demonstrated preserved activation and deactivation of lexical-semantic information.

Relations Among Tasks

Pearson correlations were performed that, while considered exploratory due to the relatively small number of participants with aphasia tested, can aid in further interpretation of the results. In addition, because of the extremely high scores demonstrated by Participant 5 in both Stroop error percentage and reaction time data, his data were omitted from this analysis in order to avoid any spuriously high correlations. First, I examined the relationship between the Stroop interference effects and the priming effects in the aphasic group. In theorizing how active or passive the deactivation mechanism of lexical activation might be, I predicted that, if there is an active suppressant in these early stages of processing, there would be a significant positive correlation between the measures of the Stroop test and the LPP. If, on the other hand, there was no correlation between performance on these two tasks, a more passive deactivational process could be inferred.

The Pearson correlations revealed only one significant correlation in the aphasic group between the dependent measures. The Stroop interference effect, when measured by the error percentage data, was negatively correlated with greater LPP priming at 1500 ms. As a significant positive correlation between these two measures was not evidenced at an ISI of either 500 ms or 1100 ms, it appears as though impaired Stroop inhibition and priming performance at 500 ms and 1100 ms reflect different underlying processes. The significant negative correlation between Stroop interference and LPP priming at 1500 ms can help to explain the re-emergence of reliable priming at 1500 ms.

The time course of automatic activation is known to peak early and then diminish (Neely, 1977). As priming then became evident at the longest ISI of 1500 ms, it is likely that, at least for the control group, an ISI of that length may test the limits of the LPP to distract from strategic priming effects, and, thus, reflects non-automatic, controlled processing. As for the Wernicke's aphasic group, given that a performance characterized by fewer errors on the Stroop test was significantly positively correlated with priming at 1500 ms, these individuals would be better able to generate expectancies that support priming at this ISI. In addition, the Pearson correlations revealed that the priming effect at 1500 ms was significantly positively correlated with a higher Token Test score. The combination of the findings of a positive relationship between both less impaired inhibition and a greater preservation of auditory comprehension with priming at 1500 ms suggests that the priming effect at our longest ISI reflects controlled processing in the participants with Wernicke's aphasia.

In further reviewing the correlations between the clinical-behavioral measure of auditory comprehension and Stroop and priming performance in the aphasic group, we find that the Stroop interference effect, when measured by the error percentage data, was significantly negatively correlated with a higher Token Test score. While a significant correlation between Stroop interference and performance on the Complex Ideational Material (CIM) subtest of the *BDAE* was not evidenced, this can be explained by the fact that these two tests of auditory comprehension tap into different aspects of auditory processing. The Token Test was designed to detect mild or subtle receptive deficits in aphasic patients and requires the individual to follow decontextualized and increasingly complex verbal commands. Individuals with Wernicke's aphasia are often strikingly worse in comprehending messages in isolation, benefiting greatly from contextual cues. As the major portion of the CIM involves comprehension of paragraph-length material, the greater degree of success on this subtest by the Wernicke's aphasic participants (see Appendix J) is not surprising.

Thus, the hypothesis that the severity of auditory comprehension deficits would be positively correlated with impaired inhibition on the Stroop test was supported. However, as LPP priming at 1500 ms was significantly positively correlated with a higher Token Test score in the Wernicke's aphasic group, and no reliable correlations between these two measures were obtained at ISIs of 500 ms or 1100 ms, or between any of the ISIs and CIM performance, the hypothesis that the severity of auditory comprehension deficits would be positively correlated with delayed deactivation of priming was not supported.

Theoretical Implications

The dissociation between automatic and controlled processing in this population is further reinforced. It appears that automatic processing, regarding both lexical-semantic activation and deactivation, is preserved in Wernicke's aphasia and is, therefore, not the basis for the striking deficits in auditory comprehension. However, inhibition in the Stroop test was found to be impaired, reflecting a deficit in the ability to ignore a distracting, automatically evoked stimulus. Given the significant positive correlation between the Stroop interference effect and the severity of auditory comprehension deficits, at least part of the attentional difficulties contributing to auditory comprehension reductions in this population may be attributed to impaired inhibition. This finding supports Murray et al.'s (1997) conclusions drawn from their study of attention allocation in mild aphasia. They found that while isolated attention was unimpaired in the aphasic participants, there was a disproportionate decrement in the accuracy of the aphasic group's semantic judgments, as compared with performance of normal controls, when competing stimuli were introduced, even though responses to these secondary stimuli were not required. Results from the present study are consistent with a faulty mechanism of inhibition playing a role in this reduction in attention allocation.

It has also been proposed (e.g., see Hudson, 1968) that the basis for verbal perseveration is a breakdown in inhibition. According to this theory, due to an inhibitory dysfunction, prolonged lexical activation results, and recent semantic memory traces are involuntarily recalled. While two measures of verbal perseveration were included in the correlations for the participants with Wernicke's aphasia, no significant correlations were evidenced with the Stroop interference effect.

Referring back to the summary of performance on the Rapid Naming task and the Word Fluency test in Appendix I, we see that the degree of perseveration produced by the participants with Wernicke's aphasia was fairly low. Only 8.8 percent of the aphasic group's responses (or 7.8 percent, excluding Participant 5) on the Rapid Naming task were perseverations. On the Word Fluency test, while 17.7 percent of the aphasics' responses were perseverations (or 18.8 percent, excluding Participant 5), this frequency, too, is relatively low when we compare it to a percentage of 5.8 in the normal control group. The overall small degree of perseveration in the aphasic participants is not all that surprising, given the chronic nature of the aphasia in these participants. Whereas recurrent perseveration is strongly associated with posterior aphasia (Albert & Sandson, 1986; Buckingham et al., 1979), not all Wernicke's aphasics evidence significant symptoms of perseveration. This can be particularly true when the aphasia is of long duration (e.g., Helmick & Berg, 1976). Referring to Table 1, we see that Participant 2 sustained the most recent CVA 56 months prior to testing, with the range extending to Participant 1 who sustained his CVA 177 months prior to testing. Thus, while the lack of a significant correlation between verbal perseveration and the Stroop interference effect may be due to the fact that impaired inhibition at a controlled processing level does not play a role in the manifestation of this symptom, one cannot rule out the possibility that the absence of a correlation is related to the restricted range in perseveration evidenced by the participants.

Concerning the LPP priming effects, the Pearson correlations for the aphasic participants revealed only a marginally significant negative correlation between greater perseveration on the Rapid Naming task and priming at the ISI of 1100 ms. While this finding runs contrary to our predictions, its relevance is limited by both the marginal degree of its significance and the fact that reliable priming was not obtained at 1100 ms.

Overall, however, Hypothesis 4 was not supported by the data, in that a positive correlation was not found when comparing the frequency of verbal perseveration with the Stroop interference effect or the LPP priming effects.

A final set of correlations was performed within the aphasic group, examining the possible relationship between the demographic factors of age, education, and time post-onset with Stroop and priming performance. The only significant finding was that priming at 1500 ms was negatively correlated with a higher level of formal education, a finding that is difficult to explain. Not only is the educational range extremely restricted for the participants with Wernicke's aphasia (10-12 years), but the direction of this correlation is counter-intuitive. As priming at 1500 ms was positively correlated with a higher Token Test score, one might expect a positive correlation with level of formal education, as well. However, while this should hold true for a normal population, with the onset of posterior brain damage, one would not expect education, at least in this range, to be a predictor of auditory comprehension function. Thus, while these two significant correlations do not contradict each other, the implications of the negative relationship between level of formal education and priming at 1500 ms presently remain unclear but are likely specific to the participants in this study.

Neither the factors of age nor time post-onset resulted in statistically significant correlations with the dependent measures. This may be explained by the relatively restricted range for these two factors, as shown in Table 1. Concerning age, apart from Participant 3 who was 63 years old, all of the other aphasic participants were in their low-to mid-seventies. Regarding time post-onset, while the range may appear large, from 56 to 177 months, all of the participants fall within a chronic range.

Finally, in order to add to our understanding of the testing paradigms and of the relations found among the participants with Wernicke's aphasia, Pearson correlations were conducted within the control group. Only two findings were statistically significant. LPP priming at 500 ms was positively correlated with priming at 1500 ms, a finding that reinforces the strength of the reliability of priming for the normal controls at these ISIs. In addition, greater chronological age was negatively correlated with a higher Token Test score. This finding is consistent with the normal aging literature, whereby older age is associated with a decline in comprehending complex sentence constructions (e.g., Obler et al., 1991).

One other issue that warrants comment concerns the procedure in the Stroop and priming paradigms requiring that all of the participants respond with their non-dominant left hand. This procedure was instituted in order to control for the possibility of right hemiparesis in the participants with aphasia. The question could arise as to what role the right hemisphere may play in the lexical-semantic processing of the stimulus item given such a procedure, as it is unclear what stage a participant's decision has reached when it is transferred to the right hemisphere prior to a left-handed response. MacLeod, in his 1991 review of the Stroop effect, reports a number of studies investigating hemispheric differences in producing Stroop interference and facilitation effects. Not only are the results mixed in terms of both the absence or presence of a differential effect and of the direction of the effect, but all of these studies involved presentation of the stimulus item to the right or left visual field. In the present study, the stimuli were presented in the middle of the screen to all of the participants, providing equal visual access to both hemispheres. Thus, the main effect of a left-handed response would primarily be an overall slowed response evidenced by all of the participants.

In summary, the present study was successful in confirming a number of theories in the literature concerning the impairment of inhibition in Wernicke's aphasia at the lexical-semantic level of language processing. I adapted the Stroop test to be applicable for an aphasic population and found that inhibition, as measured by this task, is impaired at the level of controlled processing in individuals with Wernicke's aphasia as compared with normal age- and education-matched controls. In addition, the data were consistent with the clinical-behavioral correlation of impaired inhibition with severity of auditory comprehension deficits. Although this study did not replicate Prather et al.'s (1997) findings of an abnormality in the priming pattern associated with Wernicke's aphasia, the confirmation of a preservation of automatic processing, along with the finding of impaired inhibition in controlled processing, supports the dissociation between these two stages of lexical-semantic processing. It also continues to support the dissociation in processing between Wernicke's and Broca's aphasia, whereas the priming pattern of the participants with Wernicke's aphasia was similar to that of the normal controls and did not reflect the slowed lexical activation previously demonstrated in Broca's aphasia (Prather et al., 1992, 1997).

We can now draw several conclusions concerning language processing in Wernicke's aphasia. As automatic lexical-semantic activation and deactivation were found to be preserved, neither slowed activation nor prolonged activation suggesting inhibitory dysfunction at this stage of processing is the basis for the disproportionate impairment of auditory comprehension. However, when controlled processing requiring attentional resources is demanded, difficulties arise, at least in part due to a faulty inhibitory mechanism. The individual with Wernicke's aphasia cannot effectively ignore the automatically evoked, distracting stimulus. This deficit is not due to more potent automatic activation, but rather due to decreased inhibition. The result of this failure is a reduction in attention allocation and in the resulting effectiveness of auditory processing.

These findings also add to the cognitive science literature, as we are able to isolate the levels of breakdown when we study a population with discrete brain damage as evidenced in Wernicke's aphasia. While research in normal aging points to a reduction in inhibitory function with age, it has been difficult for researchers to differentiate the specific process of inhibition from that of the more general age-related influence of processing speed (Earles et al., 1997; Salthouse & Meinz, 1995). In the present study, not only were the participants with Wernicke's aphasia found to be slower in performance than were the normal controls on the Stroop test, but their pattern of performance revealed a differential impairment in this measure of inhibition. Furthermore, given both the aphasic group's severity of impairment and variability in performance on auditory comprehension measures, most specifically the Token Test, it was possible to obtain further insight into the nature of the inhibitory impairment and its relationship with the severity of auditory comprehension deficits. The study was also successful in adapting an existing neuropsychological tool, the Stroop test, to be valid for use with an aphasic population.

Future Research

There are several questions that remain for future research. One question concerns the performance of individuals with Broca's aphasia on the adapted Stroop test. Although Milberg et al. (1995) demonstrated relatively preserved inhibitory function in the Broca's aphasics they tested, comparing the performance of individuals with Broca's aphasia on the Stroop test with the Wernicke's data is necessary to confirm the dissociation in inhibitory function between the aphasia types.

A second question concerns the apparent contradiction between the priming results from this study and Prather et al.'s (1997) findings. Future research should involve further examination of the priming pattern in Wernicke's aphasia by investigating performance at shorter ISIs. In the present study, priming was evidenced at the ISI of 500 ms and deactivated by 1100 ms, with performance at the ISI of 1500 ms most likely representing controlled processing for both the participants with Wernicke's aphasia and the normal controls. By investigating performance at intervals between 300 ms and 1100 ms, the activation curve would be further delineated, and a difference in deactivation of priming for the two groups might be revealed.

In addition, the present study was a group study, while Prather et al.'s (1997) findings of delayed deactivation of priming with Wernicke's aphasia were based upon a single case study. One difference in methodology between these two studies was that, in the present study, each of the 96 word pairs was presented to every participant at one ISI, but not at all three of the ISIs. In order to truly compare the results from both studies, the complete battery should be presented to every participant at each ISI.

A third area for future research concerns the relationship between inhibitory deficits and verbal perseveration. It was speculated that the lack of a significant correlation between these two factors was due to the restricted range in perseveration, most likely related to the chronicity of the aphasia in those who participated in the study. Investigating the performance of individuals with Wernicke's aphasia with more pronounced symptoms of recurrent perseveration on the adapted Stroop test should provide more information concerning the relationship between verbal perseveration and impaired inhibition.

Appendix A

Stroop test stimulus items

I. Neutral condition

X	(response "1")
XX	(response "2")
XXX	(response "3")
XXXX	(response "4")

II. Compatible condition

1	(response "1")
22	(response "2")
333	(response "3")
4444	(response "4")

III. Incompatible condition

11	(response "2")
111	(response "3")
1111	(response "4")
2	(response "1")
222	(response "3")
2222	(response "4")
3	(response "1")
33	(response "2")
3333	(response "4")
4	(response "1")
44	(response "2")
444	(response "3")

Appendix B

Priming task experimental and control words, with prime and control word frequencies per million (Francis & Kucera, 1982)

Control		Prime		Target
attic	(14)	elbow	(7)	arm
cap	(17)	cow	(28)	milk
saddle	(22)	illness	(20)	sick
criminal	(9)	envelope	(21)	letter
toy	(4)	pig	(8)	hog
total	(131)	table	(147)	chair
rush	(16)	jail	(16)	prison
limb	(4)	toad	(4)	frog
jazz	(85)	pain	(88)	ache
cattle	(94)	dinner	(91)	supper
event	(81)	river	(78)	stream
thighs	(7)	thread	(13)	needle
clue	(15)	lung	(16)	heart
report	(114)	market	(140)	store
essay	(19)	eagle	(4)	bird
voice	(220)	field	(242)	grass
perfume	(10)	dentist	(12)	teeth
thumb	(10)	broom	(2)	mop
desk	(65)	dust	(65)	dirt
despair	(20)	servant	18)	maid
anvil	(1)	camel	(1)	hump
design	(105)	doctor	(87)	nurse
task	(58)	wood	(51)	tree
soap	(21)	joke	(19)	laugh
advice	(50)	engine	(48)	motor
honor	(48)	rifle	(61)	gun
angel	(9)	apple	(8)	fruit
blister	(2)	blossom	(3)	flower
master	(49)	circle	(55)	square
frame	(69)	dream	(48)	sleep
crisis	(76)	bottle	(76)	glass
cafe	(15)	lion	(14)	tiger
streetcar	(13)	lightning	(14)	thunder
vine	(4)	sock	(3)	shoe
self	(34)	hill	(36)	mountain
picket	(9)	pillow	(8)	bed
messenger	(8)	vegetable	(10)	carrot
night	(400)	house	(388)	home
curse	(7)	spice	(2)	cinnamon

Control		Prime		Target
license	(35)	stomach	(37)	food
civilian	(8)	cucumber	(1)	salad
scale	(52)	crowd	(50)	people
straw	(15)	stove	(15)	cook
address	(68)	teacher	(77)	student
kind	(295)	door	(312)	window
advise	(8)	author	(44)	book
roller	(3)	robber	(2)	thief
plug	(21)	bend	(8)	stretch
view	(166)	floor	(157)	ceiling
mold	(43)	moon	(46)	sun
path	(44)	coat	(42)	hat
gram	(9)	gown	(16)	dress
pan	(12)	cab	(12)	taxi
trace	(13)	plate	(20)	dish
chicken	(33)	soldier	(38)	army
temper	(12)	mitten	(2)	glove
dawn	(25)	king	(25)	queen
flash	(14)	sheep	(15)	lamb
instructor	(8)	umbrella	(8)	rain
lesson	(28)	cotton	(30)	wool
praise	(13)	blouse	(1)	shirt
sailor	(4)	spider	(2)	bug
pin	(14)	pie	(13)	cake
tennis	(12)	nickel	(7)	dime
duke	(2)	fuel	(17)	oil
patron	(4)	dagger	(1)	knife
candle	(16)	castle	(6)	palace
wilderness	(9)	chocolate	(9)	vanilla
reply	(24)	ocean	(32)	sea
pride	(39)	porch	(42)	patio
dozen	(52)	smile	(48)	frown
grief	(10)	mouse	(9)	rat
puzzle	(6)	saloon	(10)	bar
glow	(13)	fork	(13)	spoon
cleaner	(4)	whisker	(3)	beard
health	(88)	bridge	(79)	tunnel
luggage	(6)	hammer	(6)	nail
class	(164)	child	(209)	baby
robe	(6)	lamp	(18)	light
part	(471)	hand	(413)	finger
flow	(55)	film	(91)	camera
sleeve	(11)	sketch	(15)	draw
shift	(25)	smoke	(32)	fire

Control		Prime		Target
fool	(30)	gate	(33)	fence
gossip	(13)	carpet	(13)	rug
echo	(6)	pony	(7)	horse
show	(72)	rock	(52)	stone
chore	(7)	shout	(3)	yell
beach	(33)	watch	(27)	time
powder	(28)	ballet	(29)	dance
sweater	(14)	sheriff	(15)	badge
stack	(7)	clown	(3)	circus
body	(271)	city	(262)	town
pepper	(12)	rabbit	(11)	hare
merit	(25)	sugar	(33)	sweet
blood	(119)	earth	(116)	soil

Appendix C

Priming task filler words and word frequencies per million (Francis & Kucera, 1982)

checker	(1)	pudding	(1)	profile	(7)
employ	(3)	monkey	(9)	aspect	(47)
wipe	(10)	side	(363)	drunk	(10)
foot	(68)	quote	(2)	election	(74)
kitchen	(90)	mayor	(8)	vice	(20)
snake	(42)	pause	(16)	radar	(23)
hair	(148)	hero	(46)	doubt	(97)
tick	(1)	can	(7)	bread	(40)
disappoint	(15)	clay	(85)	bullet	(26)
delight	(27)	rhythm	(21)	habit	(22)
cloth	(42)	key	(50)	track	(34)
study	(200)	language	(107)	avoid	(58)
death	(264)	alive	(57)	move	(36)
ride	(14)	consume	(2)	guitar	(17)
mill	(9)	library	(48)	texture	(15)
groove	(2)	silence	(49)	honest	(47)
press	(80)	brick	(18)	season	(105)
game	(121)	barn	(29)	basement	(31)
cry	(30)	horn	(14)	color	(131)
test	(94)	mouth	(103)	lounge	(5)
kitten	(5)	dune	(1)	fiction	(46)
bat	(13)	order	(342)	lantern	(13)
musician	(23)	concert	(35)	neck	(76)
noon	(24)	box	(64)	jungle	(18)
rake	(8)	forgive	(24)	deny	(46)
uncertain	(22)	camp	(65)	hotel	(84)
spell	(14)	install	(8)	exact	(27)
taste	(53)	park	(48)	influence	(112)
song	(56)	wisdom	(42)	amazement	(10)
flood	(15)	den	(2)	kid	(54)
matter	(281)	journal	(6)	gold	(36)
exposure	(24)	flavor	(16)	diet	(20)
sample	(54)	plaster	(23)	concept	(83)
fun	(43)	gesture	(32)	fortune	(23)
stairs	(46)	freshman	(8)	aim	(27)
reward	(13)	urgency	(12)	driver	(48)
pencil	(34)	session	(77)	harbor	(16)
brown	(4)	escape	(18)	preserve	(3)
cupboard	(2)	estate	(48)	grape	(3)
bell	(14)	gray	(5)	present	(43)

pitch	(21)	post	(55)	rent	(8)
await	(9)	cop	(14)	mark	(36)
notice	(30)	boy	(235)	horizon	(27)
baseball	(54)	mustard	(18)	car	(270)
rag	(7)	mail	(37)	neon	(12)
loop	(15)	decade	(46)	fresh	(79)
judge	(22)	corn	(38)	burn	(5)
hoof	(1)	church	(223)	plot	(32)
iron	(35)	arise	(28)	poet	(68)
future	(106)	cigarette	(25)	wise	(33)
fry	(2)	kick	(10)	breakfast	(53)
list	(125)	witness	(18)	trial	(117)
news	(90)	shop	(49)	half	(14)
gum	(14)	vacation	(46)	slug	(8)
comet	(1)	shaft	(11)	nice	(74)
ridge	(12)	smooth	(6)	print	(14)
mansion	(7)	novel	(48)	joy	(40)
marble	(18)	bubble	(12)	garage	(19)
crew	(36)	golf	(27)	rule	(58)
process	(191)	column	(59)	mobile	(26)
fact	(446)	debate	(30)	ham	(14)
wash	(21)	hall	(106)	past	(99)
noun	(1)	lobby	(19)	nobody	(74)
pursue	(20)	sharp	(71)	tower	(12)
goodness	(16)	pulse	(8)	garden	(46)
decision	(119)	science	(111)	tension	(55)
hunter	(7)	land	(192)	beauty	(68)
treat	(2)	fighter	(9)	finance	(9)
crane	(1)	belly	(23)	daughter	(72)
turnpike	(6)	public	(135)	timber	(19)
crawl	(9)	flag	(15)	damage	(27)
farmer	(23)	gem	(4)	bulk	(13)

Appendix D

Priming task pronounceable nonwords

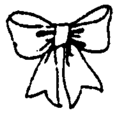
afe	alde	ane	arve	ast	athe
aze	ancyque	aneg	anif	anip	annit
arkuf	arpuf	artsel	autid	avit	ayak
aza	azat	amarmek	arditry	arepist	barve
bem	bepp	bip	biss	blard	blide
blopt	blost	borm	bost	bruve	buce
bedorm	beegrel	befnob	bera	bimpton	biny
bired	birit	bisler	bizing	blassip	bleatest
bluyip	bolyet	braxely	bregol	brilking	brofter
bucy	barmery	bebilin	cade	carn	ceeth
ceff	chag	chaick	choe	chone	choop
cipt	cleb	clesh	clift	clipe	clume
colk	crix	crope	cump	curth	champer
chartest	chemy	chiving	cisume	clarak	clasted
clithert	conyop	coover	coptid	crinted	cufster
cussebum	dack	darse	deast	demp	dirst
dost	dreat	dride	debbin	delif	delsur
dermerth	dervil	destalk	dezfal	dilbin	dobin
domarf	drapter	dridle	durvist	dusel	drajobo
ealt	eape	easot	efig	egnan	epide
erute	esset	etserp	exxy	elaso	erpretso
esola	etenig	evinug	famp	feep	fint
flep	floz	foat	foft	folf	folt
foomb	fosp	fost	frinck	fupp	fafer
faffel	falloom	fephort	fesme	fetop	filsod
finjint	fiswag	flotso	fofter	fogeldt	folis
fora	foslim	fotef	frojunt	froplin	fupet
fosreny	fuftelly	garge	garse	gerst	girm
grelk	gasip	gemmers	gertin	ginul	glifee
glisty	gomarf	gontri	grefed	gribo	grooney
gedimer	genomarp	getiar	gotapid	hape	heast
hink	horpe	hurge	hegna	henop	hoctor
hompsy	horep	horgell	hortick	hosek	hudle
insip	irmal	jarp	jeft	jikes	jost
jurst	jalange	javet	jenkle	jiffint	joover
jorzel	kelse	kiv	klife	kilnob	kirple
koffert	koyam	krungip	krunkle	kufar	kuner
kevetil	korpacter	lang	lepp	lig	loff
lork	lub	ludge	lun	lund	lachmir
lafef	laquib	larmus	laslip	lepner	letins
libeen	limaf	limmer	lipin	lirem	lirmit

lisof	logfit	lomself	lontews	lonzolm	lorgez
lorner	lorney	lozef	larydom	lefnigey	lobrozo
lunderlop	lunkerpy	malk	marste	meethe	mins
moff	murst	mafon	mallock	martel	masrey
maydoth	mebber	melorge	melost	melpnor	merseg
mipor	mirto	moia	mokal	molwag	moquep
moserl	mulbon	mussy	musten	muysek	marberry
milekum	molliop	moolary	moorpism	nace	naf
nalb	narf	narse	naul	nilp	nimed
nog	nost	nuk	nuld	nump	nuth
nabet	naelus	nagen	nahned	nallop	nalue
nanga	nealip	neflig	nelits	nelpo	neluck
neneg	nephort	nerler	nermip	nian	nikrit
nitan	nivop	nolits	nolrey	norler	nourept
nuckbo	nulpni	nuvelt	natipeff	nicosim	nifegly
nigyfig	nimollek	nitoliss	nofobe	numnipaz	obbs
ong	ort	orve	odof	olog	olsem
onso	orphime	ossy	ovrom	olarmy	onrooney
oporfy	oquro	osinap	pelm	plape	plenk
pliff	plin	plome	plost	poff	prape
prill	pringe	prout	pruld	prup	pumm
parment	patker	peffir	peram	pidar	pitum
plefir	plimet	polet	pooncy	poorfy	prilod
protog	pulder	puzbe	pagotib	palenter	pazinmum
pirugin	quoor	quomp	quancy	quasmi	quister
rab	rems	rert	rog	rolb	romt
roolf	rull	ruve	radic	raelor	raleb
rebmeb	rebo	regnobs	regpos	reli	remmil
renops	repa	riflip	rigmil	risten	roflop
rofmock	rofpink	roftek	roldy	rompi	roquo
ruep	rupinge	repmoso	retamil	retmial	rettlibo
rizozon	rofpuny	rupongor	sart	setes	shoog
sibz	siln	sim	sloaf	slig	smur
snerk	snim	snulch	spluft	steck	stroock
suss	sabim	santen	sarkuft	savlos	seenats
semdra	senoz	seran	serdem	seveph	sevnits
silpom	sintast	sismau	slartny	snaefip	snaetig
socnim	solmer	sordtri	sormel	stadep	stelast
suals	sufpolt	suobs	surap	surme	susek
suzhoff	sweton	swoka	sargussy	sentenri	sokentiff
sumebuc	tafe	tarse	teanst	thid	tice
tisp	tist	traw	troobe	trub	tul
tumst	talpnern	talserm	tanpeif	taquas	tavin
tebbhu	tebnis	tellobes	temra	temsift	terpar
teru	teses	tewshu	tibo	tida	tiglys

tijurn	tikven	tirnik	tivealt	toem	tollebs
tolsof	tomrof	torek	tormak	tosol	trildig
tropun	trosdrid	trupni	tuggno	talpnea	tavelis
temigy	tidua	tratully	turfia	tursaki	tysenlap
udort	umdreg	uqueem	usek	usseck	ulatsoit
utalsto	unterloo	vate	veek	vock	vorg
vatin	vawift	vaxo	vetip	volheap	vopil
voslig	vullen	vutness	velikit	wemse	wobe
woff	wudge	wump	wust	wagna	walba
wampler	wasby	wegmer	wengy	wifler	wipso
wobteg	wocar	wolmag	wopled	weolner	widnulo
yob	yalmo	yarnap	yelop	yerick	yolter
yoonerg	yorept	yosler	yotrep	zaff	zin
zolk	zon	zallob	zaluny	zironoz	zonnelia

Appendix E

Perseveration naming task picture stimuli (Snodgrass & Vanderwart, 1980; Abbate & LaChappelle, 1978), target word responses, and word frequencies per million (Francis & Kucera, 1982)

Primes	Targets			Controls
				
hat (54)	vest (3)	mitten (2)	sock (3)	barrel (23)
				
car (270)	truck (56)	train (67)	bus (34)	bow (11)
				
horse (112)	skunk (1)	giraffe (1)	camel (1)	whistle (3)

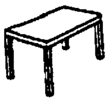
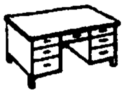

			

table (147)	bench (27)	lamp (18)	desk (65)	anchor (15)
				
piano (30)	trumpet (6)	harp (1)	flute (1)	flag (15)

Appendix F

Stroop mean reaction times (in ms) of correct responses for participants with Wernicke's aphasia and normal controls

Participants	Compatible Condition	Neutral Condition	Incompatible Condition
Aphasics:			
Participant 1	963	1000	1179
Participant 2	1306	1404	1433
Participant 3	1027	1067	1176
Participant 4	885	927	1069
Participant 5	2116	2350	3201
Participant 6	1182	1181	1412
mean:	**1247**	**1322**	**1578**
s.d.:	**452**	**531**	**808**
mean (exclud. subj. 5):	**1073**	**1116**	**1254**
s.d. (exclud. subj. 5):	**170**	**187**	**160**
Controls:			
Participant 7	1031	1028	1085
Participant 8	1297	1319	1400
Participant 9	814	841	868
Participant 10	844	873	884
Participant 11	967	997	1008
Participant 12	801	807	828
Participant 13	996	990	1045
Participant 14	769	830	839
Participant 15	907	917	977
Participant 16	955	976	970
Participant 17	899	921	955
Participant 18	919	927	971
mean:	**933**	**952**	**986**
s.d.:	**140**	**135**	**153**

Appendix G

Stroop error percentages for participants with Wernicke's aphasia and normal controls

Participants	Compatible Condition	Neutral Condition	Incompatible Condition
Aphasics:			
Participant 1	2.86	4.17	6.94
Participant 2	0	0	0
Participant 3	0	1.45	5.80
Participant 4	0	0	8.70
Participant 5	0	1.92	89.55
Participant 6	3.03	0	1.45
mean:	**0.98**	**1.26**	**18.74**
s.d.:	**1.52**	**1.65**	**34.85**
mean (exclud. subj. 5):	**1.18**	**1.12**	**4.58**
s.d. (exclud. subj. 5):	**1.61**	**1.81**	**3.70**
Controls:			
Participant 7	0	0	1.45
Participant 8	0	0	4.29
Participant 9	0	0	1.39
Participant 10	0	2.82	4.23
Participant 11	0	0	2.82
Participant 12	0	0	0
Participant 13	0	0	2.78
Participant 14	0	1.39	1.43
Participant 15	0	0	0
Participant 16	0	0	1.39
Participant 17	0	0	2.86
Participant 18	0	0	0
mean:	**0**	**0.35**	**1.88**
s.d.:	**0**	**0.87**	**1.52**

Appendix H

List Priming Paradigm mean reaction times (in ms) for participants with Wernicke's aphasia and normal controls

Participants	ISI 500 ms		ISI 1100 ms		ISI 1500 ms	
	related	control	related	control	related	control
Aphasics:						
Participant 1	1054	1122	990	1045	1099	1146
Participant 2	835	943	932	923	961	1175
Participant 3	701	699	582	617	604	653
Participant 4	667	716	678	693	742	721
Participant 5	1079	1071	945	902	960	995
Participant 6	753	813	803	837	789	880
mean:	**848**	**894**	**822**	**836**	**859**	**928**
s.d.:	**179**	**180**	**164**	**158**	**180**	**216**
mean (exclud. subj. 5):	**802**	**859**	**797**	**823**	**839**	**915**
s.d. (exclud. subj. 5):	**155**	**176**	**170**	**172**	**193**	**239**
Controls:						
Participant 7	680	690	648	689	682	688
Participant 8	839	907	890	899	862	927
Participant 9	579	599	567	588	550	581
Participant 10	631	634	589	611	632	666
Participant 11	587	569	519	523	539	542
Participant 12	562	622	549	562	514	566
Participant 13	623	652	672	699	671	725
Participant 14	569	615	598	569	562	576
Participant 15	601	614	582	579	607	617
Participant 16	587	635	581	587	608	604
Participant 17	659	612	672	671	624	617
Participant 18	607	613	592	623	608	594
mean:	**627**	**647**	**622**	**633**	**622**	**642**
s.d.:	**76**	**87**	**96**	**99**	**91**	**104**

Appendix I

Rapid Naming task and Word Fluency test tabulations of whole-word perseverations (W-W), part-word perseverations (P-W), total number of responses (T-resp), and percentage of overall perseveration (% persev) for all participants

Participants	Rapid Naming task				Word Fluency test			
	W-W	P-W	T-resp	% persev	W-W	P-W	T-resp	% persev
Aphasics:								
Participant 1	3	5	248	3.2	2	2	38	10.5
Participant 2	21	9	250	12.0	9	0	27	33.3
Participant 3	7	3	243	4.1	0	0	5	0
Participant 4	20	5	246	10.2	0	0	9	0
Participant 5	20	17	268	13.8	1	0	8	12.5
Participant 6	7	18	267	9.4	0	2	4	50.0
mean:	**13.0**	**9.5**	**253.7**	**8.8**	**2.0**	**0.7**	**15.2**	**17.7**
s.d.:	**8.2**	**6.5**	**11.0**	**4.3**	**3.5**	**1.0**	**14.0**	**20.0**
mean (excl. subj. 5):	**11.6**	**8.0**	**250.8**	**7.8**	**2.2**	**0.8**	**16.6**	**18.8**
s.d. (excl. subj. 5):	**8.3**	**6.0**	**9.4**	**3.9**	**3.9**	**1.1**	**15.1**	**22.1**
Controls:								
Participant 7	1	0	244	0.4	8	1	90	10.0
Participant 8	1	0	243	0.4	2	1	63	4.8
Participant 9	1	2	246	1.2	12	1	85	15.3
Participant 10	0	0	240	0	1	1	45	4.4
Participant 11	1	2	244	1.2	1	0	65	1.5
Participant 12	2	0	242	0.8	1	0	36	2.8
Participant 13	0	0	240	0	2	0	62	3.2
Participant 14	1	0	243	0.4	5	0	56	8.9
Participant 15	1	0	240	0.4	2	2	57	7.0
Participant 16	0	0	241	0	4	0	62	6.5
Participant 17	1	2	244	1.2	2	0	68	2.9
Participant 18	1	0	240	0.4	2	0	82	2.4
mean:	**0.8**	**0.5**	**242.3**	**0.5**	**3.5**	**0.5**	**64.3**	**5.8**
s.d.:	**0.6**	**0.9**	**2.1**	**0.5**	**3.4**	**0.7**	**15.7**	**4.0**

Appendix J

Token Test and Complex Ideational Material (CIM) raw scores and accuracy percentages for all participants, accompanied by severity ratings for the aphasic group

Participants	Token Test			CIM		
Aphasics:	**raw score**	**% correct**	**severity**	**raw score**	**% correct**	**severity**
Participant 1	85/163	52.2	severe	7/12	58.3	moderate
Participant 2	104	63.8	mod-severe	5	41.7	mod-severe
Participant 3	93	57.1	severe	8	66.7	mild-mod
Participant 4	73	44.8	severe	6	50.0	moderate
Participant 5	62	38.0	severe	4	33.3	severe
Participant 6	96	58.9	mod-severe	9	75.0	mild
mean:	**85.5**	**52.5**	-	**6.5**	**54.2**	-
s.d.:	**15.6**	**9.6**	-	**1.9**	**15.6**	-
mean (excl. subj. 5):	**90.2**	**55.3**	-	**7.0**	**58.3**	-
s.d. (excl. subj. 5):	**11.8**	**7.2**	-	**1.6**	**13.2**	-
Controls:						
Participant 7	160/163	98.2	-	11/12	91.7	-
Participant 8	162	99.4	-	11	91.7	-
Participant 9	163	100.0	-	10	83.3	-
Participant 10	157	96.3	-	11	91.7	-
Participant 11	156	95.7	-	12	100.0	-
Participant 12	163	100.0	-	11	91.7	-
Participant 13	163	100.0	-	12	100.0	-
Participant 14	163	100.0	-	11	91.7	-
Participant 15	162	99.4	-	12	100.0	-
Participant 16	163	100.0	-	12	100.0	-
Participant 17	163	100.0	-	11	91.7	-
Participant 18	157	96.3	-	10	83.3	-
mean:	**161.0**	**98.8**	-	**11.2**	**93.1**	-
s.d.:	**2.8**	**1.7**	-	**0.7**	**6.0**	-

References

Abbate, M. S., & LaChappelle, N. B. (1978). *Pictures, please! A language supplement.* Tucson, AZ: Communication Skill Builders.

Albert, M. L., & Sandson, J. (1986). Perseveration in aphasia. *Cortex, 22,* 103-115.

Balota, D. A., Black, S. R., & Cheney, M. (1992). Automatic and attentional priming in young and older adults: Reevaluation of the two-process model. *Journal of Experimental Psychology: Human Perception and Performance, 18,* 485-502.

Battig, W. F., & Montague, W. E. (1969). Category norms for verbal items in 56 categories: A replication and extension of the Connecticut category norms. *Journal of Experimental Psychology Monographs, 80* (3, Pt. 2).

Berg, T., & Schade, U. (1992). The role of inhibition in a spreading-activation model of language production. I. The psycholinguistic perspective. *Journal of Psycholinguistic Research, 21,* 405-434.

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

Borkowski, J. G., Benton, A. L., & Spreen, O. (1967). Word fluency and brain damage. *Neuropsychologia, 5,* 135-140.

Broadbent, D. E. (1970). Stimulus set and response set. In D. I. Mortofsky (Ed.), *Attention: Contemporary theories and analysis.* New York: Appleton-Century-Crofts.

Buckingham, H. W., Whitaker, H., & Whitaker, H. A. (1979). On linguistic perseveration. In H. A. Whitaker & H. Whitaker (Eds.), *Studies in neurolinguistics, Vol. 4.* New York: Academic Press.

Chenery, H., Ingram, J., & Murdoch, B. (1990). Automatic and volitional semantic processing in aphasia. *Brain and Language, 38,* 215-232.

Chmiel, N. (1984). Phonological recoding for reading: The effect of concurrent articulation in a Stroop task. *British Journal of Psychology, 75,* 213-220.

Cohen, J. D., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: An interactive graphic system for designing and controlling experiments in the psychology laboratory using Macintosh computers. *Behavior Research Methods, Instruments and Computers, 25,* 257-271.

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

Crider, A. (1997). Perseveration in schizophrenia. *Schizophrenia Bulletin, 23,* 63-74.

DeRenzi, E., & Vignolo, L. A. (1962). The token test: A sensitive test to detect receptive disturbances in aphasics. *Brain, 85,* 665-678.

Earles, J. L., Connor, L. T., Frieske, D., Park, D. C., Smith, A. D., & Zwahr, M. (1997). Age differences in inhibition: Possible causes and consequences. *Aging, Neuropsychology, and Cognition, 4,* 45-57.

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). "Mini-Mental State": A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research, 12,* 189-198.

Fox, L. A., Shor, R. E., & Steinman, R. J. (1971). Semantic gradients and interference in naming color, spatial direction, and numerosity. *Journal of Experimental Psychology, 91,* 59-65.

Francis, W., & Kucera, H. (1982). *Frequency analysis of English usage: Lexicon and grammar.* Boston: Houghton Mifflin.

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

Goodglass, H., & Kaplan, E. (1972). *The assessment of aphasia and related disorders, First edition.* Philadelphia: Lea & Febiger.

Goodglass, H., & Kaplan, E. (1983). *The assessment of aphasia and related disorders, Second edition.* Philadelphia: Lea & Febiger.

Hagoort, P. (1993). Impairments of lexical-semantic processing in aphasia: Evidence from the processing of lexical ambiguities. *Brain and Language, 45,* 189-232.

Hagoort, P. (1997). Semantic priming in Broca's aphasics at a short SOA: No support for an automatic access deficit. *Brain and Language, 56,* 287-300.

Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view. In G. H. Bower (Ed.), *The psychology of learning and motivation, Vol. 22.* San Diego, CA: Academic Press.

Helmick, J. W., & Berg, C. B. (1976). Perseveration in brain-injured adults. *Journal of Communication Disorders, 9,* 143-156.

Henik, A., Dronkers, N. F., Knight, R. T., & Osimani, A. (1993). Differential effects of semantic and identity priming in patients with left and right hemisphere lesions. *Journal of Cognitive Neuroscience, 5,* 45-55.

Hudson, A. (1968). Perseveration. *Brain, 91,* 571-582.

Jenkins, J. J. (1970). The 1952 Minnesota word association norms. In L. Postman & G. Keppel (Eds.), *Norms of word associations.* New York: Academic Press.

Keppel, G., & Strand, B. Z. (1970). Free-association responses to the primary responses and other responses selected from the Palermo-Jenkins norms. In L. Postman & G. Keppel (Eds.), *Norms of word associations.* New York: Academic Press.

MacLeod, C. M. (1991). Half a century of research on the Stroop effect: An integrative review. *Psychological Bulletin, 109,* 163-203.

Maher, B. A. (1983). A tentative theory of schizophrenic utterance. In B. A. Maher & W. B. Maher (Eds.), *Progress in experimental personality research, Vol. 12.* New York: Academic Press.

Marshall, G. R., & Cofer, C. N. (1970). Single-word free-association norms for 328 responses from the Connecticut cultural norms for verbal items in categories. In L. Postman & G. Keppel (Eds.), *Norms of word associations.* New York: Academic Press.

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

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

Milberg, W., Blumstein, S. E., Katz, D., Gershberg, F., & Brown, T. (1995). Semantic facilitation in aphasia: Effects of time and expectancy. *Journal of Cognitive Neuroscience, 7,* 33-50.

Morton, J. (1970). A functional model for memory. In D. A. Norman (Ed.), *Models of human memory.* New York: Academic Press.

Murray, L. L., Holland, A. L., & Beeson, P. M. (1997). Auditory processing in individuals with mild aphasia: A study of resource allocation. *Journal of Speech, Language, and Hearing Research, 40,* 792-808.

Neely, J. H. (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.

Neely, J. H. (1991). Semantic priming effects in visual word recognition: A selective review of current findings and theories. In D. Besner & G. U. Humphreys (Eds.), *Basic processing in reading: Visual word recognition.* Hillsdale, NJ: Erlbaum.

Obler, L. K., Albert, M. L., Goodglass, H., & Benson, D. F. (1978). Aphasia type and aging. *Brain and Language, 6,* 318-322.

Obler, L., Fein, D., Nicholas, M., & Albert, M. L. (1991). Auditory comprehension and aging: Decline in syntactic processing. *Journal of Applied Psycholinguistics, 12,* 433-452.

Ostrin, R. K., & Tyler, L. K. (1993). Automatic access to lexical semantics in aphasia: Evidence from semantic and associative priming. *Brain and Language, 45,* 147-159.

Posner, M. I., & Snyder, C. R. R. (1975). Attention and cognitive control. In R. L. Solso (Ed.), *Information processing and cognition: The Loyola symposium.* Hillsdale, NJ: Erlbaum.

Postman, L. (1970). The California norms: Association as a function of word frequency. In L. Postman & G. Keppel (Eds.), *Norms of word associations.* New York: Academic Press.

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

Prather, P. A., 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.

Rafal, R., & Henik, A. (1994). The neurology of inhibition: Integrating controlled and automatic processing. In D. Dagenbach & T. H. Carr (Eds.), *Inhibitory processes in attention, memory, and language.* San Diego, CA: Academic Press.

Revonsuo, A. (1995). Words interact with colors in a globally aphasic patient: Evidence from a Stroop-like task. *Cortex, 31,* 377-386.

Salthouse, T. A., & Meinz, E. J. (1995). Aging, inhibition, working memory, and speed. *Journal of Gerontology: Psychological Sciences, 50B,* P297-P306.

Sandson, J., & Albert, M. L. (1984). Varieties of perseveration. *Neuropsychologia, 22,* 715-732.

Santo Pietro, M. J., & Rigrodsky, S. (1982). The effects of temporal and semantic conditions on the occurrence of the error response of perseveration in adult aphasics. *Journal of Speech and Hearing Research, 25,* 184-192.

Santo Pietro, M. J., & Rigrodsky, S. (1986). Patterns of oral-verbal perseveration in adult aphasics. *Brain and Language, 29,* 1-17.

Sarno, M. T. (1969). *The functional communication profile.* New York: New York University Medical Center, Rusk Institute of Rehabilitation Medicine.

Schvaneveldt, R. W., & Meyer, D. E. (1973). Retrieval and comparison processes in semantic memory. In S. Kornblum (Ed.), *Attention and performance IV.* New York: Academic Press.

Shallice, T. (1988). *From neuropsychology to mental structure.* Cambridge, England: Cambridge University Press.

Shelton, J. R., & Martin, R. C. (1992). How semantic is automatic semantic priming? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18,* 1191-1210.

Shor, R. E. (1971). Symbol processing speed differences and symbol interference effects in a variety of concept domains. *The Journal of General Psychology, 85,* 187-205.

Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory, 6,* 174-215.

Spreen, O., & Benton, A. L. (1969). *Neurosensory center comprehensive examination for aphasia.* Victoria, B. C.: University of Victoria, Department of Psychology, Neuropsychology Laboratory.

Stern, C., Prather, P., Swinney, D., & Zurif, E. (1991). The time course of automatic lexical access and aging. *Brain and Language, 40,* 359-372.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18,* 643-662.

Sullivan, M. P., Faust, M. E., & Balota, D. A. (1995). Identity negative priming in older adults and individuals with dementia of the Alzheimer type. *Neuropsychology, 9,* 537-555.

Tipper, S. P. (1985). The negative priming effect: Inhibitory priming by ignored objects. *The Quarterly Journal of Experimental Psychology, 37A,* 571-590.

Tseng, C. -H., McNeil, M. R., & Milenkovic, P. (1993). An investigation of attention allocation deficits in aphasia. *Brain and Language, 45*, 276-296.

Vitkovich, M., & Humphreys, G. W. (1991). Perseverant responding in speeded naming of pictures: It's in the links. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17*, 664--680.

Whitehouse, P., Caramazza, A., & Zurif, E. B. (1978). Naming in aphasia: Interacting effects of form and function. *Brain and Language, 6*, 63-74.

Windes, J. D. (1968). Reaction time for numerical coding and naming of numerals. *Journal of Experimental Psychology, 78*, 318-322.

Wingfield, A., Goodglass, H., & Lindfield, K. C. (1997). Separating speed from automaticity in a patient with focal brain atrophy. *Psychological Science, 8*, 247-249.

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