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Controlled priming effects via manipulating the relatedness proportion in nonfluent aphasia

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CONTROLLED PRIMING EFFECTS VIA MANIPULATING THE RELATEDNESS PROPORTION IN NONFLUENT APHASIA

by

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Abstract

CONTROLLED PROCESSING EFFECTS VIA MANIPULATING THE RELATEDNESS PROPORTION IN NONFLUENT APHASIA

by

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This project examines the claim in the neuropsychology literature that Broca's-type aphasic adults demonstrate controlled processing (the ability to develop strategies for word recognition of semantically related word pairs). The most prominent work supporting the existence of controlled processing in this population is that of Milberg and Blumstein (1981) who used a semantic judgment task to measure controlled processing. However, the examination of this question is more optimally accomplished by use of a priming paradigm with a lexical decision task as this paradigm better isolates component processes underlying word recognition. In the work presented here, relatedness proportion is manipulated to evoke expectancy-based strategies. The results suggest that Broca's aphasics do not demonstrate controlled processing. That is, they do not demonstrate an increase in priming as relatedness proportion increases. Instead it seems the Broca's subjects tend to show inhibition effects for related word pairs. These results are discussed in terms of prospective and retrospective semantic processes that are believed to be dissociable in the model of normal lexical access.

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I. INTRODUCTION

The nature of lexical processing and organization are central to the study of aphasia. Widely disparate explanations have been postulated to elucidate loci of disruption for lexical processing found in aphasia, with variable access to open/closed class words (Bradley, Garrett, Zurif, 1980), and the breakdown in processing unstressed functor words (Kean, 1985) being among the more familiar approaches. One other major approach has been the use of lexical (semantic) processing as a means for exploring the structure of the mental lexicon and the apparent disruption thereof in aphasia. In a series of studies, the Milberg group (Milberg and Blumstein 1981; Blumstein, Milberg, and Shrier 1982; Milberg, Blumstein, and Dworetsky, 1987) utilized the priming paradigm in examining profiles of lexical abilities in aphasic adults. Their findings have proven to be important but controversial (Swinney, Zurif, Nicol, 1989; Prather, Zurif, Stern, and Rosen, 1990; Hagoort, 1990; Chenery, Ingram, & Murdoch, 1990; Katz, 1988, Henik, Dronkers, Knight, Osimani, 1992) as will be discussed in detail later. The investigation of the component lexical processes involved in the complex task of word recognition as revealed by the priming paradigm in aphasic processing constitutes the theme of research to be explored in this paper.

A. PRIMING EFFECTS AND THE DUAL PROCESS THEORY

Automatic activation and controlled priming effects have come to be recognized as two basic forms of lexical processing (Posner and Snyder, 1975 a,b; Collins & Loftus, 1975; Neely, 1976, 1977; for review see Neely, 1991; Tweedy, Lapinski, & Schvaneveldt, 1977). Automatic activation is obtained when two semantically related words are presented rapidly in succession. Activation is assumed to "spread" from the initial word's representation to the subsequently presented related word's representation via the "semantic network" (Collins and Loftus, 1975), resulting in the decrease of processing time for the subsequently presented word (referred to as semantic facilitation). This mechanism is considered to be automatic because it is apparently an inhibition-free, obligatory process, for which attentional allocation is not required. Some investigators argue that activation is not truly automatic, as focusing attention on the prime as a whole word, rather than letter by letter, is required (Henik, Friedrich, & Kellogg, 1983; Ratcliff and McKoon, 1985). However, such activation can be considered to be automatic in the sense that after the prime is processed as a whole word on a semantic level, an automatic process results, which entails spreading activation to related words. As den Heyer notes: "Automatic spreading activation need not be correlated with prime processing in that prime processing may involve an attentional component, but it does not mean effects of the prime on the target can't be automatic" (den Heyer et al. 1983, p. 380).

In contrast, controlled processing is an attention-driven, strategy-based cognitive process, elicited under conditions during which subjects formulate a strategy (typically unconscious) regarding the nature of the relationship between two stimuli. The act of attending to a specific relationship affects the response latency required to process the target word, such that the processing time is sped up for words that conform to the expected relationship and is slowed for the words that violate the expected relationship. When subjects' expectations are fulfilled, then the reaction time is even faster than that of facilitation resulting from the effects of automatic spreading activation. Conversely, if the subjects are expecting related words (such as doctor-nurse), then the recognition time for unrelated words (such as butter-nurse) is slowed (semantic inhibition), due to the violation of the expected relationship. The studies conducted in this paper involve a detailed investigation of the effects of semantic priming on word recognition in aphasia, with a focus on the issues surrounding automatic/controlled processing effects on lexical access.

Posner and Snyder (1975 a,b) were among the first to formalize the component mental operations of automatic and controlled processing in terms of facilitation and inhibition effects. Their dual process model accounted for priming phenomena in terms of facilitation and inhibition effects and made specific predictions regarding the co-occurrence of such effects. The task frequently used to measure such effects is called the lexical decision task, during which subjects must decide whether the second word of the word pair, called the target word, is a word or a nonword. Each target is preceded by a prime which may or may not be semantically related. Subjects make lexical decisions to target words only. They press a labelled button to register their answer as a "YES" or "NO" decision regarding the target's lexical status. Reaction times are measured from the time of target stimulus onset to the point of response. In order to tease out facilitatory and inhibitory effects, it has been arued that three conditions must be tested, over which priming words vary but target words are held constant. The neutral condition consists of a priming word that is as semantically neutral as possible, in that it does not activate other words via the semantic network (e.g., "blank"), or does so minimally, and holds no semantic relationship to the subsequent target word[1]. Alternative

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[1]Choosing a truly neutral baseline has been the topic of much debate. For example, when the neutral prime "XXXXX" was compared to the prime "blank", de Groot, Thomassen, and Hudson (1982) found that Ss were slower in RTs to "XXXXX", as compared to "blank". Thus, using "XXXXX" may overestimate facilitatory effects and underestimate inhibitory effects. This result serves to highlight care needed in choosing a prime for the neutral baseline condition (see also Jonides and Mack, 1984).

prime words are either semantically related or semantically unrelated to the target, yielding reaction times to be compared with the neutral trials to determine whether the effect of relatedness facilitated or inhibited processing time. In summary, facilitation is quantified by faster processing rates for the target word when it is preceded by a semantically related prime, as compared to the neutral condition. Inhibition is measured as longer reaction times in the presence of semantically unrelated words in the neutral condition. Posner and Snyder argue that the presence of inhibition reflects controlled processing (Collins & Loftus, 1975; Posner and Snyder, 1975 a,b; Neely, 1976,1977).

Controlled priming processes produce robust, well-replicated, facilitatory and/or inhibitory effects in normal adults (Neely, 1976, 1977; Neely, Keefe, & Ross, 1989; Tweedy, Lapinski, & Schvaneveldt, 1977; Tweedy & Lapinski, 1981; Becker, 1980; den Heyer, 1985; den Heyer, Briand, Dannenbring, 1983; de Groot, 1984). The nature of controlled processing has been widely investigated and is thought to reflect the development of expectations as well as strategies over experimental trials. As a result of expectancy, the relationship of facilitation to inhibition is somewhat complex. With respect to controlled processing, the facilitatory effects are larger than the facilitation elicited under conditions set up to elicit automatic processing. In contrast, an absence of inhibition usually indicates that controlled processing has not occurred and, in such a case, any facilitation present is considered to be purely automatic, lacking the attention-driven, controlled component.[2]

B. RELEVANCE OF THE PRIMING PARADIGM TO APHASIOLOGY

Using the priming paradigm in conjunction with a lexical decision task serves to isolate the component lexical processes in word recognition. These are the very processing routines that are obscured in complex, off-line tasks commonly used to assess lexical organization, such as semantic clustering by, for example, sorting cards. Three processes elicited during the lexical decision task have been delineated by Neely and his colleagues, namely: automatic spreading activation, expectancy, and semantic matching (Neely & Keefe, 1989; Neely, Keefe and Ross, 1989). A substantial amount of converging evidence supporting such a three-process theory of word recognition has been obtained by a large number of researchers (Chiarello et al. 1990; 1992; Lorch, Balota & Stamm, 1986; den Heyer, 1985; de Groot, 1984; den Heyer et al. 1983, presented in detail later).

The motivating factor in the current study is that there has

[2] One exception to this general rule is found when using small, semantically defined sets, such as antonyms. In this case, inhibitory effects are not elicited in the controlled condition but facilitation effects are (i.e., "facilitation dominance", Becker 1980).

not been an attempt to identify the status of the various semantic processing routines in aphasia. In particular, there has been no report of an adequate study of controlled processing using the priming paradigm with a lexical decision task. Such a study, designed to be precisely analogous to those in the literature on normal subjects, may provide necessary evidence that can bolster the normal model if the findings were interpretable in terms of disruption of one or another isolable processes in the normal model. The ultimate goal of the experimental work done here is to constrain the normal model and look to see if neurologic resources are dissociable. Implementing the priming paradigm, which has proven to yield significant insight into ways of normal semantic processing, can only clean up the aphasiology literature and begin to bridge the gap between psycholinguists and neurolinguists. In this way, it is possible to build a unified theory of lexical processing, by forcing cognitive scientists to account for the data derived from aphasics with disordered lexical access as well as that of normals; data that are presented in the same form, derived from the same tasks using identical paradigms and experimental designs.

Semantic priming has become important to aphasiologists for many reasons. Priming is clearly related to the semantic cuing technique so prevalently employed in aphasia therapy; when the aphasic patient is having difficulty retrieving an elusive target word, the presentation of a semantically related word may facilitate the access and production of the target (Stimley & Noll, 1991; Li & Williams, 1991; but see Blaxton & Bookheimer, 1992). Semantic cuing is one of the most powerful clinical techniques in eliciting meaningful language from some mildly or moderately impaired aphasic adults, virtually across all aphasia types. Similarly, the notion of semantic facilitation is incorporated in diagnostic instruments for example, the **Boston Naming Test** (Goodglass, Kaplan, & Weintraub, 1983) and the **Western Aphasia Battery**, (Kertesz, 1982). The measurement of the facilitation in naming via semantic cues can serve as a prognostic indicator of the patient's ability to develop a semantic self-cuing strategy. Thus, cuing in one sense or another has been shown to be a robust clinical technique, yet little of its detailed operation in aphasics is known. Such work may allow us to clarify the component mental operations of semantic cuing, as well as delineate reasons why some aphasics do not benefit from semantic cues. The semantic priming paradigm may be a useful vehicle to discern the underlying mechanisms of semantic cuing, and ultimately lexical access.

While no study carefully examining controlled processing in aphasia with appropriate techniques exists, questions concerning lexical processing in anterior and posterior aphasia have been approached using the automatic/controlled framework. A number of aphasiologists have focused on the distinction between lexical organization and lexical access in explaining lexical deficits in aphasia (see e.g., Milberg & Blumstein, 1981; Blumstein et al., 1982). The priming paradigm proved useful in resolving which explanation is more plausible, access or organization. A brief review of the history of that work is in order.

During the 1970's, many investigators concluded the organization of words and their meanings to be the primary impairment for Wernicke's aphasics, but not Broca's, who performed qualitatively similarly to normals. The tasks used to demonstrate lexical organization defects were contrived and off-line, with subjects generally required to sort cards into semantic categories or judge whether two words were semantically related (Goodglass & Baker, 1976; Zurif, Galvin and Meyerson, 1974). Difficulty in performing such tasks was considered to indicate a disordered lexical system underlying some word finding problems in aphasia. However, a confounding variable appears to have been operating throughout these studies. The problem of establishing a metalinguistic set requiring sustained attention over several minutes in the verbal domain may ultimately shape performance and will likely underestimate the aphasic's true capabilities. Moreover, the problem of an impaired working memory for verbal material may prove to influence aphasic subjects' behavior on such tasks.

Sustaining attention to task parameters may be a burden, and hence a consideration for any researcher. The work of Martin and her colleagues, among others, is beginning to tease out these cognitive aspects and their interplay with language breakdown in aphasia (Martin & Fehrer, 1990; Martin & Romani, 1992). Finally, note that stimuli considered to be related in tasks involving off-line, semantic judgments need not be those representations linked along a semantic network. Indeed these stimuli used in semantic judgment tasks may not elicit semantic priming effects. Neely (1977) pointed out that performance on a semantic sorting task may reflect inferences and comparisons, rather than "semantic structures connected by automated associative links" (p. 253).

The debate over whether to attribute word finding difficulties to lexical organization or to lexical access continued into the 1980's. With the introduction of an on-line use of the priming paradigm, investigators were able to circumvent the mental set and cognitive requirements of the aforementioned tasks via priming, designed to assess activation among lexical nodes in semantic memory, regardless of verbal memory and other cognitive-linguistic limitations (Posner & Snyder, 1975a,b; Collins & Loftus, 1975). The essential benefit in experimentation using the priming paradigm is the capacity to measure lexical processes as they unfold, on the scale of milliseconds. Priming effects are discerned even when stimulus words are subthreshold and subjects cannot report having seen the prime word (Marcel, 1983; Carr and Dagenbach, 1990; Dagenbach, Carr, & Wilhelmsen, 1989; Forster & Davis, 1991). By using the priming paradigm, aphasiologists have begun to gain insight into the question of lexical access versus organization. Through its use, lexical organization can be examined in terms of the integrity of the semantic network, which is revealed through the presence of priming effects.

The finding of a double dissociation relevant to this issue in aphasia was put forth in work by Milberg and Blumstein, 1981; Blumstein et al., 1982; Milberg et al., 1987. They presented evidence that fluent aphasic adults (e.g., Wernicke's-type) do indeed demonstrate automatic spreading activation effects on a priming task, but show severe impairment on a semantic judgment task[3]. These authors concluded that the organization of the lexicon is considered to be intact relative to the impaired volitional access of lexical items. However, the nonfluent subjects (e.g., Broca's-type) showed the reverse pattern; automatic priming was not found, yet performance on a semantic judgment task was accurate. Hence, nonfluent

[3]Note that, given current knowledge of priming, conclusions from these studies are problematic as the interstimulus intervals (between prime and target) used were two seconds (prime durations were unspecified), a time too long to provide trustworthy evidence of automatic priming.

aphasics were viewed by these authors as having deficits in spreading activation with relatively spared controlled processing.

The Milberg group (1981, 1982, 1987) made interesting claims regarding the automatic priming effects, but did not use the priming paradigm to elicit the volitional, attention-driven, type of lexical retrieval. Instead, they used an off-line semantic judgment task to demonstrate volitional lexical access. Because it is problematic to assume any off-line semantic-based task elicits controlled processing, the Milberg group's work may not reflect controlled processing. Moreover, the presence of controlled processing, by definition, can be elicited in the on-line priming paradigm with careful consideration of experimental parameters such as stimulus onset asynchrony, proportion of the related words in the stimulus list, and the number of nonwords. The point to be underscored here is that testing aphasic subjects in a priming paradigm set up to evoke controlled processing would greatly enhance our understanding of the loci of processing breakdown in terms of the substantial literature established on normal adults (Neely, 1976, 1977; Becker, 1980; den Heyer, Briand, & Smith, 1985; Lorch, Balota, & Stamm, 1986; Tweedy, Lapinski & Schvaneveldt, 1977; Tweedy & Lapinski, 1981; de Groot, 1984; Chiarello, Burgess, Richards, & Pollack, 1990; Chiarello, Richards, & Pollack, 1992). However, findings from priming studies on aphasics will optimally map into the literature on normals only to the degree that the methods, experimental designs and paradigms used in research on aphasia are parallel to those guiding the research on normals.

Other reasons for looking at controlled effects in an aphasic population relate to the analogy between the lexical decision task, used within the priming paradigm, and language comprehension. Chiarello, Richards, and Pollack (1992) and de Groot (1984) argue that language comprehension involves accessing meanings of words, which must be assessed as to whether they fit with previous meanings; and, if so, integrated into the overall meaning, or context. If the meaning is anomalous to the established context, then a revision is necessary either to reinterpret the word meaning or to revise the prevailing context. Chiarello et al. go so far as to propose that "meaning comparison processes used in the lexical decision task may be derived from that used in ongoing language comprehension" (p.54, 1992). Various controlled processes (namely expectancy and relatedness checking, to be discussed later) may very well be common cognitive operations used in language comprehension. The priming paradigm serves to break such a complex task as word recognition down into component processes, which are likely to be used routinely in language comprehension. Implementing the lexical decision task with the priming methodology enables us to isolate and track the unfolding of such processes. For this reason, all of the studies reviewed and carried out here focus on the lexical decision task only. In contrast, using a pronunciation task (e.g., naming the target word instead of making a lexical decision to it) would not evoke the full spectrum of controlled processes, which are of interest here. Specifically, semantic matching (see Neely & Keefe, 1989) is not relevant to pronouncing the target word and is not elicited, but expectancy is. In summary, only ASA and expectancy may affect pronunciation time in a naming task. Thus a lexical decision task is the preferred methodology for the current work.

A brief summary follows concerning priming phenomena associated with the lexical decision task using word pairs in the literature on aphasia. (Unless otherwise noted, the following studies involve the lexical decision task with word pairs and the semantic priming paradigm.) This literature consists of some conflicting results. In general nonfluent, Broca's-type aphasics have not reliably demonstrated automatic priming, whereas fluent, Wernicke-type aphasics always do (Milberg et al. 1981; 1982; 1987; Katz, 1988; Chenery et al., 1990; Henik et al. 1992). Specifically, the Milberg group's findings (1981, 1987) suggest that automatic facilitation effects are relatively spared for fluent aphasics, but impaired for nonfluent subjects, in that nonfluent subjects showed an unreliable priming effect for the semantically related condition. However, in their 1982 study, Blumstein et al. report that nonfluent aphasics did demonstrate priming effects of the automatic type. Such data imply markedly deviant lexical processing compared to normals and fluent aphasics.

In an attempt to replicate Milberg and colleagues' findings, Chenery et al. (1990) and Katz (1988) found reliable facilitation effects for the nonfluent aphasics, as opposed to the Milberg et al. 1981 and 1987 data. However, Henik et al. (1992) did not find effects of automatic spreading activation for either fluent or nonfluent aphasics. Such data are again inconsistent with the findings of Milberg and Blumstein (1981) who found facilitation for fluent aphasics. These studies are among many that provide conflicting evidence about whether nonfluent aphasic adults are capable of demonstrating automatic priming effects. Refer to Appendix I for a summary of studies using sentences as experimental context (Swinney, Zurif, & Nicol, 1989; Hagoort, 1990) and studies using continuous lists (Prather et al., 1990).

Much work in the literature has gone into defining the experimental parameters under which automatic and controlled processing occur and the possible cognitive operations leading to priming events in normal adults (Posner & Snyder, 1975a,b;

Neely, 1976,1977, for review, see Neely, 1991; Marcel, 1983). The following literature review focuses on normal word recognition, with respect to automatic and controlled lexical processing. Next, design considerations with respect to neurogenic language dysfunction are presented. Finally, new results from the present research on controlled processing using the priming paradigm with aphasics is presented.

C. CONCEPTUAL FRAMEWORK: FINDINGS ON NORMAL ADULTS

To reliably differentiate automatic and controlled processing, the relatedness proportion is varied as a standard experimental manipulation. Manipulating the relatedness proportion, or the probability of the occurrence of semantically related versus unrelated trials throughout the course of the stimulus list, results in the development of expectations, and thus strategies on the part of the subject. The standard manipulation in the literature on normals is a high relatedness proportion of 80% related, with the low relatedness proportion being 20% related (Tweedy et al., 1977; den Heyer, Briand, Dannenbring, 1983; de Groot, 1984). Altogether, these studies serve as compelling evidence for the probability of semantic relatedness over trials as being a reliable method for eliciting strategy-evoking controlled, lexical processing. The following literature review will highlight aspects of the prediction-based, controlled processing induced by the relatedness proportion manipulation in normal adults. Data regarding automatic spreading activation and other forms of controlled processing will be presented only to the extent they elucidate this probability-driven strategy of interest.

Tweedy, Schvaneveldt, and Lapinski (1977) presented the preliminary data on the effects of relatedness proportion, which led to substantial insight into controlled processing. These authors demonstrated that embedding related word pairs into lists that were loaded with semantically related word pairs (e.g., high relatedness proportion) results in markedly faster recognition time for related words, compared to the case where these words were embedded into lists which were not semantically loaded (e.g., low relatedness proportion). Certainly, the discovery that probability computations (resulting in the development of expectations) influence lexical decisions was useful in elucidating controlled processing phenomena in that it provided a way to reliably induce strategic processing. These results spurred further investigation into the nature of expectancy influencing lexical decisions to related words (den Heyer et al., 1983; den Heyer, 1985; de Groot, 1984; Neely, Keefe, & Ross, 1989). However, Tweedy et al.'s work left open the question of the time needed to invoke attentional mechanisms underlying the relatedness proportion effect. A critical prediction of the Posner and Snyder (1975) theory is that sufficient time is needed between the onsets of the prime and target (called stimulus onset asynchrony, henceforth referred to as SOA) in order for the prime-induced attentional processing to be effective. Therefore, one could test this prediction to determine whether the size of priming effect would increase concurrently with relatedness proportion, only when SOAs are adequately long for subjects to engage in controlled processing. This is exactly what the following investigators did.

Both den Heyer et al. (1983) and de Groot (1984) manipulated the relatedness proportion using the same priming paradigm as Tweedy et al. (1977), but tested for priming effects at various SOAs and included a neutral baseline condition to tease out inhibitory and facilitatory effects. Den Heyer et al. used SOAs of 75 and 1000 ms and a neutral prime of "XXXXX"; while de Groot used 240, 540, 1040 ms and the neutral prime "blank". A priming curve for lexical decisions for semantically related words can be derived by grouping their findings. At an SOA of 75 ms, facilitation secondary to automatic spreading activation is found without inhibitory effects. At SOAs of 240, 540, and 1000 ms inhibitory and facilitatory effects are apparent; but at 1040 ms, only facilitation is detected. Moreover, de Groot measured the effect of relatedness proportion on the magnitude of priming by using four relatedness proportion conditions: 25%, 50%, 75%, 100%. She found that the 75% relatedness proportion is effective in eliciting a dramatic increase of facilitation, indicative of controlled processing. The 100% relatedness proportion condition was not significantly different from the 75% relatedness proportion condition in eliciting controlled effects. Den Heyer et al. found an increase in facilitation and inhibition as relatedness proportion increases, but de Groot found only an increase in inhibition as relatedness proportion increases. Taken together, the results of these studies provide critical information regarding the time course of priming effects as mediated by the relatedness proportion manipulation.

Den Heyer (1985) attempted to replicate his 1983 study and boosted his statistical power by increasing the number of subjects per group. He was interested in relative facilitation and inhibition effects with respect to increases in relatedness proportion. In comparing 11% relatedness proportion with 89% relatedness proportion, den Heyer showed that both facilitation and inhibition increase as relatedness proportion increases. Den Heyer's explanation for this increase centers around Neely's (1977) predict and match strategy, for which a relatedness checking mechanism is postulated. If relatedness exists, then a bias towards a "YES" response is present, as the subject has learned that under a high relatedness proportion condition, relatedness predicts lexicality. In this way, "YES" responses are sped up. However, if the word pair is unrelated, a subject is biased toward a "NO" decision, which is incompatible with the correct lexical decision and thus slows decision time. Neely proposed that the predict and match strategy is triggered by the processing of the prime word[4]. De Groot (1984) renamed this strategy as the post-lexical coherence check and claimed it is instigated after the target is processed. In either event, den Heyer claimed such a mechanism explains why inhibition increases as relatedness proportion increases.

In addition, questions regarding experience and practice effects were examined. In their 1981 study, Tweedy and Lapinski further manipulated high and low-biased relatedness proportion to find the extent to which such a prediction strategy would prevail over unbiased trials. Subjects, who were biased toward either 100% or 0% probability of relatedness, showed only facilitation on subsequent 50% related trials. These data suggest that subjects did not develop a semantic-based strategy at this point, as predictions did not carry over from either of the preceding biasing trials and inhibition was not shown. However, after subsequent reversed biasing trials (subjects who initially had

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[4]Neely's account now has developed to include three processes, automatic spreading activation, expectancy, and semantic matching (Neely, Keefe, Ross, 1989; Neely & Keefe, 1989) with the number nonwords being crucial in eliciting component processes.

100%, now saw 0% relatedness, and vice versa for the other

group of subjects), the same subjects did show a carryover relatedness effect when responding to the immediately following 50% probability trials. Specifically, reaction times to the 50% probability trials were a function of the preceding biasing trials' relatedness proportions. The authors concluded that subjects needed time and experience to build up predictions strongly enough to show carryover onto the subsequent 50% probability trials, as such results were found only in the latter part of the study. The main outcome of this research was to show that the relatedness proportion effect was indeed strategic in nature.

Den Heyer (1985) provided some evidence regarding a different aspect of the strategy mediating the relatedness proportion effect. His study addressed the question of whether practice or experience affects the speed of implementation of the expectancy strategy associated with the relatedness proportion effect. He found, using a lexical decision paradigm, that practice did not impact on the magnitude or direction of priming effects. He concluded that "the strategic mechanism represents a general verbal mechanism and it is invoked rapidly during the course of administering a high relatedness proportion condition," (1985, p.28). This conclusion seems to conflict with that of Tweedy and Lapinski, as experience did play a role in their results. The difference in SOAs could contribute to these inconsistent results. In the Tweedy and Lapinski study, the SOA was as long as the subject took to respond plus 100 ms, and thus it was uncontrolled, with subjects responding to every word (both prime and target). In den Heyer's study SOA was limited to 550 ms and subjects responded to targets only. Overall, both studies provide support for the strategic nature of the relatedness proportion effect, but further study of the role of SOA is needed.

Controlled processing is now considered to be a category under which different lexical processes may fall. The classification of a number of controlled processes has been the focus of much research (Lorch, Balota, & Stamm, 1986; den Heyer, Briand, & Smith, 1985; den Heyer, 1985; de Groot, 1984; Becker, 1980). The refinement in the conceptualization of strategy-driven controlled processing hinges on the different sorts of strategies subjects may develop. One such strategy type is typically termed "pre-lexical" or "prospective" and occurs between the presentation of the prime and the target, while another is called "post-lexical" or retrospective and is deemed to occur after the target has been processed. Both types of strategies are considered to be controlled processing, as they take place after the automatic spreading activation is induced initially by the prime.

The focus of the research to be presented here is on the effect of using a high relatedness proportion, to provide conditions for controlled processing by leading subjects to predict the target word from the prime word. This prediction strategy is commonly viewed as happening before the presentation of the target, and therefore is considered to be a prospective, pre-lexical strategy. The SOA between the prime and target words must be long enough for the subject to formulate expectations, at least 250 ms (de Groot, 1984; Neely, 1977). At the other extreme, the longest SOA at which expectancy-based controlled processing has been found to occur is 3250 ms (Balota, Black, & Cheney, 1992).

To illustrate more fully the notion of pre-lexical, prospective processing, a brief discussion of Becker's semantic verification hypothesis is warranted. Becker found that the manipulation of the semantic relationship between the prime and target (such as category/exemplar vs. antonym priming) can lead to distinctively different priming effects. Category/exemplar word pairs produce inhibition outweighing facilitation, termed inhibition dominance, while antonym pairs lead to the reverse, or facilitation dominance. Becker (1980) postulated that subjects generate a set of semantically related words from a prime word and check the target word against this semantic set. This set is formed while the sensory analysis of the target continues to its completion.

This strategy is considered to be pre-lexical because it supposedly occurs before the sensory representation of the target is established. Becker explained the phenomena of facilitation dominance and inhibition dominance in terms of the time it takes to check the candidates in the semantic set for a match against a partial sensory representation of the target. He argued that when a superordinate category name is presented, the number of semantically related words generated from the prime word is far greater than for an antonym prime. The effect of inhibition on making a lexical decision is greater when the semantic set is large, due to the long time needed to check the large semantic set. In the case of category/exemplar word pairs, this extended time leads to what Becker calls inhibition dominance. Only facilitation effects are found with smaller sets, as in the case of antonym pairs, because semantic verification is accomplished by checking very few semantic candidates. Likewise, this causes facilitation dominance. These dominance effects implicating prospective, pre-lexical processing have been replicated, and debated, by den Heyer et al. (1985) and Lorch et al. (1986). Important to consider here is that the semantic verification strategy is another example of pre-lexical, prospective controlled processing.

Certainly distinguishing between pre- and post-lexical processing is not always a straightforward endeavor. Neely, Keefe, and Ross (1989) have provided critical evidence showing how other confounding elements may interfere with the relatedness proportion effect and the development of pure expectancy-based, strategies. In fact, Neely and his colleagues showed that an additional post-target strategy is induced as a result of one aspect of the standard experimental design concerning the lexical decision task, that is the nonword ratio. Neely's group's findings are elaborated here because they distinguish a retrospective strategy from a prospective expectancy-based strategy induced secondarily to the effect of nonword ratio. Neely et al. proposed that through the inclusion of a high nonword to word ratio (the ratio of nonwords to the sum of the nonwords plus unrelated words targets) in the lexical decision paradigm, a post-lexical, retrospective strategy becomes cost-effective for subjects to utilize. These investigators proposed that subjects check for semantic relatedness between the prime and the target, because determining relatedness speeds up reaction time. They argued that the advantage in using such a retrospective strategy is that by determining relatedness, lexicality of the target is simultaneously known. When using the lexical decision task in conjunction with the priming paradigm, and a high nonword ratio (e.g., 83%), relatedness does indeed predict lexicality of the target as all related trials consist of words, requiring a lexical decision of "yes". By lowering the nonword ratio (e.g., 25%), and minimizing such a retrospective strategy, effects associated with retrospective processes are also minimized, such as the nonword facilitation effect[5]. Although accounting for these priming phenomena is beyond the scope of this paper, it is useful to note that a reasonable amount of evidence supports such a retrospective strategy.

The discovery of the influence of the nonword ratio on retrospective processing has had considerable impact on theory-building efforts centered on priming phenomena. The crucial implication is for future experimental design. The nonword ratio must be held low in order to avoid a confound of a post-lexical, retrospective operation, if the focus is on prospective processing. This control would apply to any study

[5]A particularly vexing finding has been that of the nonword facilitation effect, or the faster RT to a nonword when preceded by a word prime as opposed to a neutral prime (e.g., "XXXXX"; Neely, 1976). This finding posed a problem for the original two-process theory of automatic and attentional processing (Posner & Snyder, 1975), which was formulated in terms of prospective processing. A retrospective semantic matching strategy accounts for this effect. The strategy involves Ss checking for relatedness between the target and prime words, after the target is accessed. The benefit of using such a strategy is that relatedness predicts the target's lexicality. Thus its usefulness is an artifact of the lexical decision task. (Such a retrospective strategy is not induced in the pronunciation task, as Ss are required to name the target rather than making a lexical decision. Voice onset time is measured to quantify priming effects). If the prime and target words are not related, as for a word prime and a nonword target, then the decision mechanism is biased toward a "no" response. This bias speeds up reaction time and hence the semantic matching strategy is facilitatory in nature. In the case of a neutral prime "XXXXX" and a nonword target, the relatedness check is not performed, and hence the reaction times are longer relative to the word-nonword condition.

of the relatedness proportion effect, which is viewed as a strictly prospective, expectancy-based computation.

In elucidating the effects of nonword ratio, Neely refined his notions of Posner and Snyder's dual process theory (1975) and his predict and match strategy, both of which were strictly prospective in nature. Neely now claims that a three-process, "hybrid" theory, involving both prospective and retrospective processes, better explains the constellation of findings in the priming literature (Neely & Keefe, 1989). Neely proposes that the processes elicited during the lexical decision task entail automatic spreading activation, expectancy, and a semantic matching strategy. Expectancy and the matching strategy are considered to be controlled processes, expectancy being prospective, and semantic matching retrospective. Expectancy occurs when using a priming paradigm in which the relatedness proportion is high, and the nonword ratio is kept low (e.g., 25%). In addition, a semantic matching strategy occurs when the nonword ratio is high. By proposing such a post-lexical strategy, Neely can account for a broad range of findings, such as why low dominance category-exemplars are primed in a lexical decision task, but not in a naming task[6].

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[6]Neely et al. (1989) show how the nonword ratio modulates subjects' utilization of retrospective semantic matching strategy by looking at priming effects for high and low dominance category-exemplar word pairs (e.g., bird-robin; bird-vulture, respectively). In manipulating the nonword ratio, and teasing out retrospective processes from prospective processes, priming of low dominance exemplars is accounted for. By definition, high dominance

D. CONTROLLED PROCESSING AND APHASIA

As suggested in Section B the question remains open as to whether the Milberg group actually studied aphasics' capacity for controlled processing. The use of a proper task to elicit controlled processing is critical in order to separate controlled processing from automatic effects in determining whether either is spared in aphasia. The definitive paradigm used to elicit controlled processing is the semantic priming paradigm, and the normal model of word recognition is built on data using this paradigm. Controlled processing occurs under experimental conditions where there is sufficient time between the prime and target words to allow for attention-driven processing, such as that induced by a stimulus list containing a high probability of semantically related words (den Heyer et al., 1983; Tweedy et al., 1977, 1983) and these effects have not yet been evaluated with aphasic adults.

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exemplars are generated from the category prime, and low dominance exemplars are not. Therefore, priming effects for category-high dominance exemplars are considered to be a result of expectancy generated from the prime word, while priming for low dominance exemplars is thought to be due to post-lexical processing. Evidence supporting this position is the finding of greater priming effects for low dominance exemplars with the lexical decision task than for the pronunciation task (Keefe & Neely, 1988; Lorch et al., 1986). Manipulating the nonword ratio was found to determine whether priming for low dominance exemplars was obtained. For example, when the nonword ratio is kept low, then retrospective processing is minimized and priming for low dominance exemplars decreases, but priming for high dominance exemplars is robust. Conversely, when the nonword ratio is high, then retrospective processing is encouraged and priming effects for low dominance exemplars are obtained.

There is some reason to question whether aphasic adults would be able to demonstrate normal automatic and especially controlled processing within the parameters of the priming paradigm. The findings on normal adults imply the left hemisphere may serve as the neural substrate for the slower, volitional, controlled processing. Some compelling experimental evidence to that effect comes from work by Chiarello and her associates (Chiarello, 1985; Chiarello, Burgess, Richards, & Pollack, 1987; Chiarello, Richards, & Pollack, 1992) who show that controlled effects are mostly mediated by the left hemisphere. The Chiarello group provides a neuroanatomic framework within which word recognition in left hemisphere-lesioned aphasics can be interpreted, in that the left hemisphere seems capable of controlled processing, while the right hemisphere is so capable only under limited conditions. Their conclusions (for review see Chiarello, 1988a,b; Chiarello et al., 1990, 1992) indicate that the left hemisphere subserves two processes fundamental to word recognition, the selection of appropriate word meanings (requiring the inhibition of lexical competitors) and the integration of the selected word into the sentential context. The right hemiphere, however, may play the role of maintaining a broad range of candidate words, from which the left hemisphere seems to make a selection via inhibiting inappropriate lexical candidates competing with the target word. The right hemiphere-function of maintaining potential target words may be necessary for drawing the verbal inferences required to comprehend abstract language, such as for sarcasm, humor, and metaphor interpretation (Chiarello, 1988 a,b).

Additionally, substantial motivation for investigating controlled processing in aphasia comes from the notion that a target word's semantic associates can no longer be inhibited during lexical access, as the mechanism that inhibits lexical competitors is dysfunctional (Luria, 1973). Concrete support for this position is that verbal paraphasias are frequently observed as naming errors in aphasia. Considering that the left hemisphere seems to mediate controlled processing in word recognition, the questions asked in the proposed studies here emerge directly from the literature on normal adults; the question as to whether left hemisphere-lesioned adults are able to demonstrate controlled processing. Here the controlled processes of interest involve generating expectancies from the prime word and possibly checking the semantic relationship between the prime and target words.

E. RESEARCH OBJECTIVES

Milberg and co-researchers (1981, 1982, 1987) put forth the hypothesis that nonfluent aphasic subjects demonstrate controlled processing on a semantic judgment task, but not automatic spreading activation when using a priming paradigm.

However, no study to date has measured controlled processing using a priming task, explicitly set up to elicit controlled processing. Therefore, the objective here is to investigate whether controlled priming effects are discerned in a nonfluent aphasic population, under the priming conditions routinely used in the literature on normal adults (Tweedy et al., 1977; 1981; de Groot, 1984; Shiffrin & Schneider, 1977; den Heyer et al., 1983; den Heyer, 1985). Using an on-line task, such as the previously discussed controlled priming paradigm, rather than an off-line semantic judgment task, is crucial in assessing semantic processes, such as expectancy and semantic matching. The purpose of this study is to investigate priming effects, particularly controlled processing, using the definitive pairwise priming paradigm in conjunction with the lexical decision-task. The research questions are as follows:

1. GENERAL OBJECTIVE

The general objective of this project is to determine whether semantic processing deficits in nonfluent aphasia can be viewed as disruptions to isolable controlled processes, given damage to the functional architecture underlying semantic processing.

2. NARROW OBJECTIVE

Can the Milberg and colleagues' (1981, 1982, 1987) conclusion that nonfluent, Broca's-type aphasic subjects demonstrate controlled processing be supported, using the priming paradigm and lexical decision task in lieu of a semantic judgment task, in a nonfluent aphasic population parallel to their subject group?

3. IMPLICATIONS OF THE RESULTS

a. If subjects demonstrate significantly different priming effects in the high probability condition as compared to the low probability condition (e.g., semantic facilitation increases as relatedness proportion increases) then controlled processing is found.

b. The interaction between the group factor and high/low relatedness proportion factor and the related/unrelated factor must be at a significant level.

F. DESIGN CONSIDERATIONS

This study is designed to measure automatic and controlled processing by manipulating the relatedness proportion, or the probability of semantic relatedness of prime-target stimulus pairs over four blocks of trials. Two test sessions are set up to evoke strategies through a high relatedness proportion (80%), while the other two elicit only automatic priming because the probability of semantic relatedness within a stimulus-list is kept low (20% probability). Four test sessions are administered for the appropriate stimulus-list counterbalancing. The standard measurement of priming is to compare reaction times to a neutral condition, typically using the prime word "blank", and comparing the reaction times to the related and unrelated stimuli against the neutral baseline. However, the neutral trials inflate the number of test trials enormously, opposing any attempt to maintain the number of total trials at a minimum. The price for a neutral condition is high, especially when investigating a neurologically compromised population, as fatigue is a factor any investigator must consider.

In order to maintain the minimum number of test trials, neutral baseline trials may be eliminated with priming in the related condition being assessed relative to the unrelated condition. A comparison of the priming effects obtained in the low relatedness proportion trial blocks and the high relatedness proportion blocks yields the critical information of whether controlled processing indeed occurred. Specifically, the magnitude of priming for trials set up to elicit controlled processing (the high relatedness proportion trials) is compared to the extent of the priming effect from the session during which controlled processing is not evoked (the low relatedness proportion trials). If priming is greater for the former strategy-based trials than for the latter strategy-free trials, then controlled processing can be claimed to occur.

Conversely, if the magnitude of priming effects are equivalent over both sessions regardless of the strategy-inducing manipulations, then manipulating the relatedness proportion did not result in controlled processing. In such a case the consistent priming across conditions would probably be due to automatic spreading activation effects, without any contributory controlled effects. The ultimate goal of maintaining test trials to a minimum is served well by implementing a comparison of overall priming effects rather than a neutral condition to detect the occurrence of controlled processing.

An additional experimental design consideration is that of the form of the stimulus presentation, or the experimental context for the prime and target. Contexts such as word pairs, triplets, and sentences in which the prime word is embedded, yield different priming effects for aphasic adults (see Appendix I for summary; Hagoort, 1990; Milberg & Blumstein, 1981; Blumstein et al., 1982; Milberg et al., 1987; Katz, 1988; Swinney et al., 1989). Moreover, findings for normal adults suggest that different lexical processes are evoked as a function of context being either sentences or word triplets (Swinney, 1979; Schvaneveldt, Meyer, Becker, 1976). The bulk of psycholinguistic research on normal word recognition concerns the processing of word pairs, and thus in the interest of interpreting the data in terms of the normal model, consistency with the design used for normal subjects is a goal. Given the overriding interest of consistency with the methods used to build the normal model, word pairs are preferred in investigating abnormal word récognition.

Indeed, the decision to use word pairs rather than sentences, may stand solely on the grounds that the research project considered here involves aphasic adults, who have considerably more difficulties parsing sentences than words. The choice of a word pair paradigm would lead to more reliable performance, and hence data, across aphasia types. Finally, a motivation for using word pairs is the analogy of the word pair stimuli to the semantic cuing technique. Experimental simulation of this clinical tool can be accomplished using word pair stimuli. Ultimately, semantic priming, using word pairs, may elucidate the component processes underlying this commonly used clinical technique.

Another design consideration is whether age-matched controls must be included. Balota, Black, and Cheney (1992) used the priming paradigm with a pronunciation task to examine the effects of age on automatic spreading activation and controlled processing. Their results effectively eliminate the need to include such a control in the study conducted here. They used a paradigm developed by Neely (1977), in which attentional processing was induced by manipulating semantic relationships between prime and target words. subjects were required to shift their attention from one category to another when specified primes appear and to expect a member of that category to appear as a target word. For example, subjects were told to expect a target of a type of fish whenever they see a prime from the category of flowers, (e.g., flower-tuna). Similar to the relatedness proportion manipulation, this paradigm evokes controlled processing, that is expectancy-based or prospective in nature, as subjects generate expectancies from the prime word.

Balota et al. tested various SOAs (250, 1000, 1750, 3250 ms) to determine the rise time and decay rates of automatic and controlled processes of young and elderly adults. They found no effect of age in terms of the priming curve for automatic and controlled processing effects. One noteworthy difference did emerge, that the prime word had to be visually available throughout the SOA to obtain these comparable effects. When the prime duration was limited to 200 ms, priming effects decayed prematurely, perhaps due to the elderly subjects' inability to inhibit extraneous thoughts and sustain their attention to the task parameters regarding expectancy. Although this is an important constraint applicable to studying the elderly, it has little impact on their conclusion that the rise time and decay rates for the young and the elderly are virtually the same. Converging evidence comes from several independent studies reporting no significant differences between young and elderly subjects in priming performance (Balota & Duchek, 1988; 1989; Chiarello, Church &

Hoyer, 1985; Howard, 1983; Burke, White, & Diaz, 1987).

The last design consideration concerns the nature of the semantic relationship between the prime and target words. The work of Chiarello and her colleagues (1985; Chiarello, Senehi, & Nuding, 1987; Chiarello, Burgess, Richards, & Pollack, 1990; Chiarello et al., 1992) provides compelling evidence that the hemispheres show differential priming effects, depending on which semantic relationship is presented. These investigators implement the visual-half field priming paradigm, to look at the effects of semantic relationships, such as category membership (e.g., lawyer-nurse), associative (e.g., bread-butter), and category plus associative (e.g., doctor-nurse) on priming profiles in each hemisphere. Their findings regarding hemisphere-specific automatic priming effects (Chiarello et al., 1990) indicate that the left hemisphere shows robust automatic priming effects for category plus associative word pairs, while hemisphere-specific effects for associative words were not found. Furthermore, the least related words, the category membership pairs, do not yield automatic priming effects for the left hemisphere, but do for the right hemisphere. These findings imply that there are separate semantic processes in each hemisphere. The authors postulate that the right hemiphere maintains distantly related associations (e.g., category words) along its "semantic network", while the left hemisphere does not. Rather, the left hemisphere commits to a target-word meaning via semantic inhibition of lexical competitors.

In their 1992 study, Chiarello and her associates manipulated the relatedness proportion with a lexical decision task in one experiment and a naming task in another to tease out effects of prospective and retrospective controlled processes, based on Neely's three process model (Neely & Keefe, 1989). They found controlled priming effects for all semantically related words (category plus associated, associated, and category only) presented to both the left hemisphere and the right hemiphere. Moreover, because these controlled priming effects occurred in both the naming and lexical decision tasks, they were attributed solely to expectancy and not to post-target controlled processes such as semantic relatedness checking. Post-target relatedness checking or semantic matching was found only in the left hemisphere. The only type of semantic relationship to produce this retrospective controlled effect was the category plus associated relationship. These authors concluded: "This dissociation implies that separate processes underlie these effects and that only one process is available to the right hemiphere....it is highly unlikely that these effects reflect the operation of a single controlled semantic process" (p. 73, 1992).

Relevant to this thesis is the finding that the full range of controlled processes (e.g., prospective and retrospective processes) seem to occur in the left hemisphere. It follows that we should expect some impairment when testing left hemisphere-lesioned subjects. In setting up the experimental design, using a high nonword ratio ensures elicitation of both pre- and post-target processes. Maximizing the chance of evoking controlled processes would enable us to answer the question as to whether aphasic subjects are able to perform controlled processes. Therefore, a high nonword ratio (83%) for the controlled, high relatedness proportion condition is used in the current study.

This overview of work by Chiarello and colleagues suggests that the left hemisphere provides the neural substrate for semantic inhibition, seemingly with limited contribution from the right hemiphere (Chiarello, 1985; Chiarello et al., 1987; 1990; 1992). Given the evidence that left hemisphere priming phenomena are most robust for the category membership plus associative semantic relationship, this semantic relationship seems optimal in the present study.

II. METHOD

A. SUBJECTS: Eleven monolingual, right handed, high school educated aphasic subjects were tested. Inclusion criteria consist of both test results and clinical impressions. Tests consisted of standard language batteries, such as the **Boston Diagnostic Aphasia Examination (BDAE)** and/or the **Western Aphasia Battery (WAB)**. Clinical findings of relevance for inclusion in this study were considered to be the presence of Broca's or transcortical motor aphasia, as characterized by nonfluent or dysfluent spontaneous speech with expressive difficulties being the primary impairment. All subjects demonstrated spared reading ability for single, high frequency words, as measured, for example, on the Word-Picture Matching Subtest from the **BDAE**. See Appendices III and IV for a summary of biographical data, test results and CT findings, when available.

Transcortical motor (TCM) aphasic subjects fit behaviorally with Broca's subjects in terms of having motoric impairment causing effortful, hesitant, dysfluent speech, with relatively spared comprehension, all of which are features of Broca's aphasia. TCM subjects were included in this study based on similarity in behavioral symptomatology to Broca's aphasics as they have been for other researchers examining nonfluent aphasic subjects for priming effects (see, for example, Blumstein et al., 1982). Inasmuch as this study is a direct examination of the Milberg et al. (1987, 1981) claims regarding nonfluent subjects' ability to show controlled processing effects, it is critical to use a subject group consisting of equivalent heterogeneity as the original study employed.

Of the 11 subjects chosen, 9 subjects were classified as Broca's and 2 as TCM aphasics. Two of the 11 subjects have had more than one CVA, and these subjects' data will be interpreted with caution (See Appendix II).

Eight neurologically intact adults between the ages of 24-39 were tested as the normal, control group. All subjects had the minimum of high school education and are currently employed at the Manhattan Veterans Administration Medical Center.

B. MATERIALS: The stimulus lists were created in accordance with the standard procedure, described in detail in den Heyer et al., 1983. The initial stimulus file is composed of 120 related words, selected within the constraints described in the Design Considerations section regarding the semantic relationship between the prime and target words. Words were chosen from the norms of semantic relatedness (Battig & Montague, 1969; Shapiro & Palermo, 1970; Whitten, Suter, & Frank, 1979), and from stimuli used in Chiarello et al. (1990)

and Milberg and Blumstein (1981). From this related list, the unrelated and nonword lists are derived in the following manner. Primes and targets are designated in the related list and are rearranged such that the primes are coupled with different targets, creating an unrelated pair. Because the designation of the prime and target remains constant for all derived lists, the reaction time to the same target can be measured in related and unrelated conditions[7]. Orthographically and phonologically legal nonword targets are derived from the original related list by changing 2 graphemes of the words designated as targets. Such alterations provide a salient nonword to the aphasic subject. Nonwords are preceded by the designated primes of the related list, and are presented only as targets. All primes are words, and precede either a nonword, unrelated target, or related target.

Target word length, frequency, and semantic relationship are held fairly consistent for the critical and filler items across both lists. Word frequency is held at an average of approximately 100, and at a minimum of 10 and maximum of 225 (Kucera & Francis, 1976). Seventy three percent of the target stimuli are 1-syllable, and 27% are 2-syllables. The type of

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[7] As semantic and repetition priming have been shown not to interact (Dannenbring & Briand, 1982; den Heyer, Goring & Dannenbring, 1985), a repeated measures design is chosen for this study in the interest of maximizing statistical power with the minimal number of Ss. In this way, Ss serve as their own control, and see the same target words in both related and unrelated trials, but never within one test session.

semantic relationship for critical trials is category membership plus associative, with the filler pairs comprised of some associative-only and some category membership as well (see Table 1). Stimuli were judged for relatedness and were rated as highly associated by monolingual, English speaking adults.

TABLE 1. STIMULUS LIST COUNTERBALANCES

FREQUENCY	**CRITICAL**	**FILLER**
0-10	0%	5%
11-50	46%	49%
51-100	37%	35%
101-150	8%	10%
>151	8%	1%
LENGTH	**CRITICAL**	**FILLER**
ONE-SYLLABLE	75%	71%
TWO-SYLLABLE	25%	29%
THREE-SYLLABLE	0%	1%
STIMULUS-TYPE	**CRITICAL**	**FILLER**
CATEGORY & ASSOCIATED	100%	74%
ASSOCIATED	0%	21%
CATEGORY	0%	4%

Four lists were created: 2 lists for the high relatedness proportion condition and 2 for the low. There were 2 lists per relatedness proportion condition to allow for unrelated primes in one list and related primes in the other list to precede the same targets in both lists. The relatedness proportion, 80% in the high condition and 20% in the low, is created by varying the number of the filler trials, while the critical, or experimental trials remain consistent at 12 related and 12 unrelated trials. Data points are measured only for critical trials. The filler trials are all related in the high relatedness proportion condition, and all unrelated in the low relatedness proportion condition; therefore the relatedness proportion is a function of the semantic relationship of the filler trials. The ratio of critical:filler:nonword trials within one test block is 24:36:60 for a total of 120 trials per block. The nonword ratio for the high relatedness proportion condition is 83%, and 55% for the low, given the reasons discussed in the Design Considerations section.

C. APPARATUS AND PROCEDURE: All stimuli were presented on an IBM XT, with a response box placed in front of the computer. The task is a lexical decision task, during which subjects see pairs of letter strings presented consecutively with each pair separated by an intertrial interval (ITI) of 2 sec. Subjects are required to decide if the second letter string is a word, as opposed to nonsensical letter strings. Subjects respond "YES" or "NO" by pressing buttons labelled as such on a response box. The instructions were formulated in order for the aphasic subjects to understand, but were also read to the control subjects in the effort for consistency of procedures for all subject groups. Instructions are: "You will see letter strings. You should decide if the string is a word or not. If it is a word, press this, labelled "YES" (investigator demonstrates). If it is not a word, press this, labelled "NO" (investigator demonstrates). For example, if you see C-A-T you press "YES". If you see X-Y-Z, you press "NO" (investigator demonstrates simultaneously with instructions). You should only respond to every other string of letters. That means just read the first one, and respond to the second one. The most important thing is to go as fast as you can. Do you understand?" Instructions are repeated as many times as necessary.

All subjects were tested on four lists over four sessions, 1 stimulus list per session. In order to counterbalance the order of list presentation, each S was presented the lists in a different order. Ten practice trials before all test sessions were given, and if the subject seemed confused, the practice trials were readministered. Subjects were told on the second, third, and fourth sessions that all the words they would see are new words they had not seen before to minimize their recognition of critical prime and target words. Each test session was approximately 5 days apart and consisted of 120 stimulus pairs. The following presentation parameters were set for the normal subjects: prime duration of 500 ms, SOA (stimulus onset asynchrony) of 1000 ms, target duration of 500 ms, and ITI of 2000 ms.

The parameters of stimulus presentation used for the aphasic subjects differed from that of the normals in terms of the durations of the prime and target words, which were determined on a per subject basis during the practice trials. In an effort to minimize errors, prime and target word durations were tested at either 1000 ms or 2000 ms to determine which was optimal for that particular subject. Each subject met the criterion of 80% accuracy during the practice trials: 5 subjects at a SOA of 2500 ms, and 6 subjects at a SOA of 1500 ms. Thus it was determined that all aphasic subjects were on the equivalent psychophysical curve. The ISI (interstimulus interval) was that used for the normals, i.e. 500 ms, as was the 2000 ms ITI (intertrial interval). Although all subjects were right handed, all chose to respond with their left hands, due to motor deficits affecting their right hands.

III. RESULTS

The raw data points (reaction times) are in the form of seconds (measured to the nearest millisecond). The raw data sets were treated as follows. The data for both aphasic and normal subjects were screened for outlier data points, defined as more or less than 2 standard deviations from that particular subject's mean. The outliers were replaced with 2 standard deviations nearest to the extreme of the outlier. Finally, in order to analyze complete data sets, missing data points were replaced with the mean reaction time derived from the subject's data corpus of the same test session. These data are presented below.

A 4-way mixed factor ANOVA (GRP X LS X HL X RU) was performed to identify effects of group (GRP: 2), list (LS: 2 lists for counterbalancing), relatedness proportion conditions (HL: high, low), and related and unrelated primes (RU). (GRP and LS were between subject factors and HL and RU were within subject factors.) As expected, list did not have a main effect nor did it participate in any significant interaction (all $Fs<1.073$). The interaction of GRP X HL X RU was significant ($F=(1,15)=7.463$, $MSe=.0009$, $p<.05$), as was the GRP main effect ($F(1,15)=10.22$, $MSe=.3652$, $p<.05$). A final ANOVA was run on the normal subjects' data, omitting the GRP factor. This ANOVA yielded the following significant effects: the HL X RU interaction ($F(1,7)=7.7816$, $MSe=.0119$, $p<.05$) and the main effect of RU ($F(1,7)=9.0475$, MSe=.0120, $p<.05$).

The mean reaction times for normal subjects for the related and unrelated stimuli in the high and low relatedness proportion conditions are given in Table 2. Note that in the high proportion condition, mean reaction times for related trials were 46 ms faster than those for the unrelated trials (i.e. 646 ms for related and 692 ms for unrelated), indicating a substantial facilitation effect. A two-tailed t test showed the related mean reaction time to be significantly different from the unrelated mean reaction time, $t(7)=3.33$, $p<.01$. However, in the low relatedness proportion condition the difference between unrelated and related mean reaction times was 2 ms (i.e., 677 ms for related and 679 ms for unrelated) $t(7)=.209$, $p>.20$, implying that facilitation effects from spreading activation have already decayed. This is reasonable to assume, given the SOA of 1000 ms. It has been argued that 250 ms may be an appropriate cutoff SOA at which automatic spreading activation is detected[8] (Neely, 1977; de Groot, 1984).

[8] Because of the overriding interest to measure controlled processing effects in aphasia, a longer SOA was needed here. In order to prevent a confound of SOA between subject groups, the longer SOA was also used for the control subjects.

Table 2. MEAN RTs FOR NORMAL SUBJECTS (MS)

HIGH RP		LOW RP	
RELATED	UNRELATED	RELATED	UNRELATED
646	692	678	680

Finally, an ANOVA on only the aphasics' data was done, eliminating GRP as a factor. The HL X RU interaction was not significant ($F(1,10)=3.227$, $MSe=.0234$, $p>.1$) nor was the main effect of RU ($F(1,10)=.0008$, $MSe=.1017$, $p>.9$).

In examining the mean RTs (see Table 3), it seems that the data for the aphasic subjects reveal a slight effect of relatedness proportion on the processing of related and unrelated stimulus pairs. The mean reaction times in the high relatedness proportion condition show a semantic inhibition effect of -18 ms (i.e. 1124 ms for related, and 1106 ms for unrelated). In the low condition, a +15 ms facilitation was found (i.e. 1123 ms for related and 1138 ms for unrelated). The striking aspect of these means is that priming decreased by 33 ms for the aphasics as relatedness proportion increased, whereas for the normal subjects it increased by 45 ms.

TABLE 3. MEAN RTs FOR APHASIC SUBJECTS (MS)

HIGH RP		LOW RP	
RELATED	UNRELATED	RELATED	UNRELATED
1124	1106	1123	1138

Two tailed t tests were done to examine the individual priming effects for the high and low relatedness proportion conditions. Neither the -18 ms priming effect for the high relatedness proportion condition (t(10)=1.01, p>.20), nor the +15 ms priming effect for the low relatedness proportion condition (t(10)=.63, p>.20) reached significance.

As shown in Table 4, an analysis of the change in the priming effects as a function of relatedness proportion demonstrates that 8 of 11 aphasic subjects showed a decrease in priming as relatedness proportion increased, 1 aphasic subject showed essentially no change, and 2 showed greater priming as relatedness proportion increased. In contrast, 6 of 8 normal subjects showed greater priming as relatedness proportion increased, with 2 subjects showing less priming. As noted earlier, for normal subjects the mean increase in priming as relatedness proportion increased was 45 ms, whereas for the aphasic subjects there was 33 ms decrease in priming. These means are significantly different (t(15)=2.731, p<.01, two tailed).

TABLE 4. CHANGES IN PRIMING WITH INCREASING RELATEDNESS PROPORTION

NL Ss	+21	-17	+91	+87	+90	-08	+48	+47			
APH Ss	-66	+98	+01	-80	-42	-38	-44	-14	-26	-158	+10

Fisher's exact test (2 tailed) was done to determine whether the proportion of subjects showing an increase in priming as relatedness proportion increases is statistically different for the normal and aphasic groups. This test yielded z=2.52, p<.05, indicating the proportion of normal subjects (6 of 8) is different from that of aphasics (3 of 11) in showing an increase in priming as relatedness proportion increases. (Note that the most conservative proportion of aphasic subjects was used, in that the subject showing a negligible +1 ms effect was treated as having shown a real increase in priming as relatedness proportion increased). In viewing the data this way, it becomes apparent that the normal subjects are influenced by relatedness proportion in a way very different from that for the aphasic subjects.

In examining Tables 2 and 4 it is evident that the priming effects for the normal subjects indicate controlled processing. Specifically, normal subjects demonstrated an increase in priming effects with an increase in relatedness proportion, consistent with previous studies on normals using a relatedness proportion manipulation and the priming paradigm (Tweedy et al. 1977; 1981; den Heyer et al., 1983, 1985; de Groot, 1984). Thus, controlled processing did occur, in the stated terms of the hypotheses.

The performance of the aphasic group (see Tables 3 and 4 and the aforementioned results of Fisher's exact test) demonstrates that these subjects were influenced by the relatedness proportion manipulation, in as much as priming effects tended to decrease as the relatedness proportion increased. The reaction time pattern for the aphasic subjects was qualitatively different from that of the normal subjects. The condition designed to elicit controlled processing seemed to cause semantic inhibition (or at least reduced facilitation) for related stimuli, in contrast to the robust increase in semantic facilitation found for normal subjects. Semantic inhibition for related word pairs is not unprecedented and the conditions under which it occurs will be discussed in the following chapter.

Errors for the normal subjects were quite low, with 3 subjects making 1-3% errors and the remaining subjects responding correctly. For the aphasic subjects, the range of outliers for the group is 4-6%, with 3 subjects showing approximately 4% outliers per data set, 2 subjects having approximately 5% outliers, and 4 subjects with 6% approximately outliers. The mean rate of errors is 12% per data corpus, the median is 11.5%, with the range at 4-19% errors. Mean reaction times, standard deviations, error rates and outlier rates per subject are listed in Table 5.

TABLE 5. MEAN RTs, SDs, ERRORS, OUTLIERS FOR APHASIC SUBJECTS

SUBJECT	MEAN RT	STANDARD DEVIATION	ERROR RATE	% OUTLIERS
JC	1872 ms	456 ms	15.6%	6.25%
BR	783 ms	125 ms	8.3%	6.25%
RH	711 ms	119 ms	11.5%	6.25%
DR	1610 ms	403 ms	19.8%	4.2%
OU	830 ms	119 ms	14.6%	4.2%
MA	752 ms	95 ms	4.2%	4.2%
GdM	1433 ms	450 ms	16.7%	5.2%
EC	1185 ms	215 ms	13.5%	6.3%
BZ	1022 ms	186 ms	4.2%	5.2%

IV. DISCUSSION AND CONCLUSION

One clear conclusion from this study is that nonfluent aphasic adults do not show the same controlled processing effects as normals in the standard pairwise semantic priming task. This result is directly opposed to the claims by the Milberg group (1981, 1982, 1987) that nonfluent aphasics do demonstrate normal controlled processing. When an experimental paradigm more sensitive to controlled processing effects is used in examining this population, normal controlled priming effects are not found. This finding bears on the double dissociation that the Milberg et al. (1987) put forth as having explanatory power for the underlying word recognition deficits in Broca's aphasia relative to Wernicke's aphasia. Regarding Broca's aphasics' deficits they stated: "The lack of consistent priming effects weakly suggests that lexical access based on automatic processing may be impaired. However, these patients appear to have little difficulty analyzing word meaning using controlled processing" (p. 140). Certainly this notion of a double dissociation is too simplistic and fails to capture the mechanisms causing lexical access difficulties in Broca's aphasia.

The finding of a tendency toward semantic inhibition in the high probability condition has certain implications for processes of lexical retrieval and loci of breakdown in aphasia. "Retrieval inhibition" for related words has been shown by Blaxton and Bookheimer (1992), who studied anomic, temporal lobe epileptic subjects. Although they used a different paradigm, their findings converge with those presented here in that semantic inhibition for related words was discovered. The method involved the presentation of word primes (1, 2, or 3 primes) before a related target. The subjects' task was to read aloud the target word after viewing the prime(s). They found that the magnitude of semantic inhibition increases proportionally with the number of semantically related primes presented. A modified version of this method was used in showing retrieval inhibition (decreased facilitation from multiple related primes) with a normal subject population (Blaxton & Neely, 1983). In either event, inhibition for semantically related words is found under such experimental conditions.

Blaxton and Bookheimer posit that anomic subjects are able to focus attention on the lexical code corresponding to the prime, but have difficulty in shifting attention to related codes, yielding inhibition for related words. They believe that the semantic store is not degraded, instead it is difficult to access given such impaired covert attentional processing. This position is in accordance with that of Luria (1972, cited in Blaxton and Bookheimer, 1992) who argues that cortical damage impairs the ability to select one target code among activated codes. Luria postulates further that codes may be activated in an abnormally equivalent manner regardless of the degree of the relatedness to the prime.

Perhaps a more satisfying account of semantic inhibition comes from the priming literature on normal adults. Recall the ultimate goal of this study was to refine the normal model by providing constraining parameters as well as supporting evidence for known phenomena associated with priming in normal adults. Experimental work done by Carr, Dagenbach, and their associates describes the particular conditions in which normals show semantic inhibition for related words, using two different priming paradigms. These studies demonstrate that two priming conditions, a masked priming paradigm and a verbal learning paradigm, lead to an unstable percept of the prime and likewise semantic inhibition for related targets.

In the case of the masked priming paradigm, Dagenbach, Carr, and Wilhelmsen (1989) varied the type of task subjects were required to perform during practice (threshold setting) trials, and then administered experimental masked priming trials using a lexical decision task, without the prior task. One group of subjects was asked to simply report detection of the prime during the practice trials, and the expected effect of semantic priming occurred for related targets during the subsequent masked priming trials. In contrast, a different group of subjects performed a semantic similarity judgment task between a masked prime and a target (i.e. subjects chose 1 of 2 clearly visible targets most semantically similar to the prime) during the set of practice trials. Surprisingly, during the subsequent masked priming trials the time required for recognition of the related targets increased significantly relative to the unrelated. These results implied that subjects persisted in strategic processing of the degraded prime, the semantic process induced during the threshold setting trials, causing inhibition of lexical access for related targets. The carryover of the preceding task into the standard priming trials caused such an effect in the case of the semantic task, while a prior semantically neutral task (e.g., the detection task) does not.

Additional experimental conditions found to elicit such effects were described by Dagenbach, Carr, and Barnhardt (1990). The methodology involved teaching subjects new words which were later used as primes. Subjects were told to think of their meaning in the interval between the prime and the target words. Again, semantic inhibition for related targets was found following newly learned prime words, which were presumably poorly established in semantic memory.

Altogether, these experiments show that the impoverished sensory input of a heavily masked prime or a weakly established, newly learned code can reliably elicit semantic inhibition for related words in normal adults. An interesting explanation was offered in Carr and Dagenbach (1990), who proposed a "center-surround" mechanism. This mechanism is established in the neurophysiology literature, in which it is a known neural principle also called lateral inhibition, holding true for the visual and tactile systems. These authors claim that under conditions of struggle in lexical access (e.g., masked prime or recently acquired word), the center-surround mechanism is automatically turned on as an aid to facilitate lexical access. The struggle itself signals the mechanism's action to be initiated. The center represents the lexical code activated by the impoverished prime word (due to masking or new learning), and the surround represents semantically related words. The action of the mechanism is to dampen the surround, or related lexical codes, in order for the weakly activated center, or code of the prime word, to "pop out". When the surround is inhibited, the center becomes more salient and accessible as a result of this contrast. In the case of a related prime and target, the percept of the prime is unstable (due to masking or new learning), and hence the related words are inhibited. In this way, semantic inhibition for related words under conditions of an impoverished sensory representation (masking) and weakly established codes (new learning) is accounted for.

This model might well apply to the data presented here on aphasic subjects. It is possible that during the struggle that is created by the presentation of the prime, the "center-surround mechanism" is turned on. Then the related words (the surround), would be inhibited while the subject attempts to access the prime word. Next, the target appears and the subject must make a lexical decision. Because the related words are now inhibited, response time to the related targets is longer. This might also explain why anomic subjects (Blaxton & Bookheimer, 1992; and this paper) tend to show semantic inhibition in a controlled priming task. The fact that inhibition tends to occur in the controlled processing condition suggests that attention-driven processing leads to the struggle and triggers the "center-surround mechanism". In contrast, automatic spreading activation does not seem to trigger such a mechanism.

Blumstein, Milberg and Shrier (1982) predicted that aphasic subjects would conform to the performance of normals on a masked priming task. "If it is the case that conscious access is impaired, then performance of aphasic subjects should be similar to normals in whom conscious access has been eliminated by means of masking. Further studies using the distinction of automatic and controlled processing may be useful in specifying spared language functions in aphasia" (p. 315). Indeed, it may be the case that aphasics' performance parallels that of normals on a masked priming task involving semantic-based manipulations, given the data presented in this thesis. At least we can state that controlled processing, as assessed by the standard priming paradigm with the lexical decision task, reveals abnormal performance on the part of Broca's aphasics. Contrary to the claims on Milberg, Blumstein, and colleagues (1981, 1982, 1987) who used a semantic jugdment task to assess controlled processing, these aphasics do NOT demonstrate normal controlled processing and may even be inhibiting related words, in contrast to the normal behavior of facilitating related words.

Future investigation into priming profiles of adults with aphasia could include manipulating the relatedness proportion over different SOAs, for example 250 ms, 1500 ms, and 3250 ms. This would allow one to determine if the decrease in priming produced by high relatedness proportions with aphasics depends on a long SOA as is so for the increase in priming produced by high relatedness proportions with normals.

The work reported here was not designed to distinguish between prospective and retrospective controlled processes. Rather the aim was to elicit controlled processing in general. Another possible follow-up to the present study would attempt to differentiate between prospective and retrospective priming effects, for instance by lowering the nonword ratio to minimize retrospective effects. Such an experimental design would allow one to determine if the prospective and retrospective volitional aspects of priming are dissociated in aphasics as they are in normals. If so, this might serve to enhance our understanding of the normal model by allowing one to determine if prospective and retrospective controlled processes are selectively impaired due to focal lesions. Whatever results such future studies may yield, the present results clearly indicate that controlled priming mechanisms are different in normal and aphasic adults.

APPENDIX I. TYPES OF PRIMING PARADIGMS AND APHASIA

Throughout the literature on aphasia, conclusions vary with respect to the type of priming paradigm used. Examples are continuous word lists, word pairs, word triplets, and sentences. Following is a summary of paradigm-dependent results, which vary between experimental contexts similarly to the data on normals.

Swinney et al. (1989) found automatic priming effects for nonfluent aphasic subjects, but they were qualitatively different from normal subjects. These researchers used ambiguous words embedded in sentences and a cross-modal priming paradigm. This involves subjects listening to sentences while making lexical decisions to a visually presented target, appearing on a computer monitor. Nonfluent aphasics showed facilitation effects for primary meanings (the higher frequency meaning) of polysemous words, independent of the preceding sentential bias. However, normal subjects showed exhaustive access of all meanings of the ambiguous word regardless of sentential bias. These effects were measured at probes immediately following the polysemous word. These findings suggest that automatic spreading activation during sentence processing, using cross-modal stimulus presentation, was present but abnormal for nonfluent aphasic subjects.

Consistent with Swinney et al., Hagoort (1990) found that anterior aphasics were able to show automatic priming effects using only the auditory modality in a sentence processing paradigm. Specifically, Broca's aphasics showed significant effects at 100 ms after a polysemous word, while Wernicke's aphasics showed a trend in this direction. Abnormalities were identified downstream in the sentence, when sentential bias failed to operate quickly (not before 750 ms). Hagoort attributed this deficit to a slowed process of integrating the sentential context with the appropriate meaning. This deficit may be viewed as a defect in attention-driven, controlled processing. Allowing the sentential context to operate in selecting the appropriate meaning of the ambiguous word is considered to be controlled processing as it requires an attentional component. Hagoort argues this degree of computational load leads to a slowing down of the integration process in Broca's aphasia. Wernicke's aphasics' performance is less clear, as their reaction times were not faster at 100 or 750 ms probes.

In order to define the range of rise time and decay of activation effects, Prather, Zurif, Stern, & Rosen (1990) examined the time course and decay of activation of words using a continuous list paradigm with one anterior aphasic subject. This paradigm is set up to minimize controlled processing by presenting words at equal intervals and subjects are required to make lexical decisions to each stimulus word.

Additionally, the design involves repeating a word, such as "word" to draw subjects' attention to an irrelevant stimulus, and distract subjects from the semantic nature of the experimental stimuli. Various stimulus onset asynchronies (hereafter SOA, being the time between the prime word onset and the target word onset) were studied (500, 800, 1500, and 1800 ms), to determine whether spreading activation is slowed. Automatic facilitation effects were obtained only at the 1500 ms SOA and found to decay thereafter. Additional testing at 500, 800, and 1800 ms SOAs failed to reveal facilitation effects for this particular aphasic subject. These results indicate a delayed rise time, with a faster decay rate in automatic spreading activation, relative to the 500-1100ms curve found for the normal elderly (Stern, Prather, Zurif, Swinney, 1991).

The purpose of presenting these studies here is to highlight the difference in priming phenomena as a function of experimental design, such as sentential, word pairs, word triplets, and continuous lists. Swinney et al. (1989) and Hagoort (1990) showed automatic priming effects for nonfluent aphasics using primed words embedded in sentences. Prather et al. (1990) found facilitation effects for a Broca's aphasic using a continuous list paradigm. However, Milberg and Blumstein (1981) showed nonfluent aphasics not able to prime with word pairs, in contrast to the positive findings of

Chenery et al. (1990) and Katz (1988), studies which explicitly set out to replicate Milberg and colleagues' work. Additional equivocal results have been found for the word triplet paradigm, as opposed to sentential paradigms (Schvaneveldt, Meyer, and Becker, 1976; Swinney, 1979; Milberg, Blumstein, & Dworetsky, 1987). The dependency on experimental context in measuring such behaviors cannot be overemphasized. A rationale for the preferred experimental context being pairwise presentation of words in the research done in this thesis is discussed in the Design Considerations section.

APPENDIX II. REANALYSIS OF DATA FOR APHASICS

In the research conducted here, inclusion criteria for the aphasic group were based primarily on behavioral data, as is true for the majority of studies in the literature (see e.g., Milberg et al., 1987, 1982; Blumstein et al. 1982; Swinney et al. 1989; Prather et al. 1990; Hagoort 1990; Katz, 1988). Moreover, neuroimaging was not available for all of the subjects tested in the experiment reported here. The overriding interest was to question a claim in the literature regarding controlled processing in a nonfluent aphasic population chosen in order to be as consistent as possible with the relevant studies (Milberg et al. 1987, 1981; Blumstein et al. 1982).

In an effort to identify effect of lesion extent on the group data, analyses omitting the 3 subjects with multiple cerebrovascular events were done. Of course, it should be kept in mind that a subject who had a single cerebrovascular event may show a larger extent of lesion than another subject who suffered more than one less serious, or "smaller" events. Nevertheless, in light of issues surrounding multiple cerebrovascular accidents, the following tests were done.

The raw data were treated with the aforementioned stabilizing techniques (see Results Section). A 4-way ANOVA (GRP X LS X HL X RU) showed that all effects involving the list factor were not significant (all Fs <2.0, all p>.05). Most importantly, the interaction of GRP X HL X RU was still significant, F(1,12)=4.80, MSe=.0007, p<.05. Also, the main effect of GRP was significant, F(1,12)=9.816, MSe=.2262, p<.01. In an ANOVA on only the aphasics' data, omitting the GRP factor, the main effect of RU nor the interaction of HL X RU were not significant (F's<1.0).

The aphasics' mean reaction times for related and unrelated stimuli in the high and low conditions are displayed in Table 7. In the high condition, the mean RT for related words was 1070 ms and for unrelated was 1073 ms, yielding a negligible 3 ms difference between conditions (t(7)=.137, p>.20, two tailed). An overall 18 ms facilitation effect (not significant at t(7)=.614, p>.20, two-tailed) was found in the low condition, with a 1090 ms mean reaction time for related stimuli and a 1108 ms mean reaction time for unrelated stimuli. Recall that the priming effect for the normal subjects (N=8) was +46 ms facilitation effect for the high relatedness proportion condition (t(7)=3.33, p<.01, two-tailed) and a nonsignificant +2 ms effect for the low condition (t(7)=.209, p>.20).

In summary, these results demonstrate that as relatedness proportion increases, priming effects for the aphasic subjects decrease (here from 18 ms down to 2 ms) as did the priming effects for the sample size of 11. The overall qualitative change (i.e., negative) in priming effects with the increase in relatedness proportion was consistent for both sample sizes of aphasic subjects. Conversely, the qualitative change for normal subjects was positive, as priming increased substantially as relatedness proportion increased (from 2 ms up to 46 ms). Note that the interaction of GRP X HL X RU is significant using both sample sizes (i.e., 8 and 11 aphasics), indicating that the relatedness proportion effect for normals and aphasics is different, regardless of sample size being 8 or 11 aphasics.

TABLE 6. MEAN RTs FOR APHASIC SUBJECTS (MS)

HIGH RP		LOW RP	
RELATED	UNRELATED	RELATED	UNRELATED
1070	1073	1090	1108

The analysis in Table 8 displays the <u>change</u> in priming effects as a function of relatedness proportion, namely the difference between the priming effects in the low relatedness proportion condition and the high relatedness proportion condition. These difference scores demonstrate that 5 of 8 (63%) aphasics showed a decrease in priming as relatedness proportion increased, 1 subject showed virtually no change, and 2 showed greater priming as relatedness proportion increased. This is comparable to the analysis for the sample of 11 subjects (see Table 4) in that 8 of 11 (73%) subjects showed a decrease in priming as relatedness proportion increases, while 1 subject showed essentially no change and 2 showed a greater priming effect. Also shown in Table 8 are the difference scores for each normal subject. Six of 8 (75%) normal subjects showed an increase in priming effects as relatedness proportion increased, while 2 showed a decrease in priming.

TABLE 7. CHANGES IN PRIMING WITH INCREASING RELATEDNESS PROPORTION FOR EACH SUBJECT

APH Ss	-66	+98	+01	-80	-42	-14	-26	+10
NL Ss	+21	-17	+91	+87	+90	-08	+48	+47

Fisher's exact test was used to determine whether the proportion of subjects showing an increase in priming as the relatedness proportion increased is significantly different for the 2 groups. This test yielded z=2.016, p<.05 (two-tailed), indicating that the proportion of subjects showing an increase in priming as relatedness proportion increased was statistically different from the sample of 8 aphasic subjects. Recall that in comparing the proportion of 11 aphasics with that of the 8 normals, the Fisher's exact test (two-tailed) was also significant (z=2.52, p<.05). Therefore, in terms of the Fisher's exact test, the data from the sample size of 8 aphasic subjects are not significantly different from the previous analysis using a sample size of 11 aphasics.

Although it is apparent that the mean reaction times for the group of 8 aphasics (see Table 7) are different from those of the group of 11, the same statistical tests on both groups yielded significant results. Specifically, the ANOVA showing the interaction of GRP X HL X RU and Fisher's exact test demonstrate significantly different performance of the aphasic group compared to that of the normal group. It is important for future studies to address localization and extent of lesion issues in a more systematic fashion than was possible here. In the research conducted here behavioral criteria were used to determine candidacy for the aphasic subject group. As these subjects fell into the behaviorally defined subject population (see Subjects section for inclusion criteria), they formed a legitimate subject group. The lack of apriori consideration of lesion site and extent precludes a deeper analysis on the data presented here.

APPENDIX III. BIOGRAPHICAL AND DIAGNOSTIC DATA FOR APHASIC Ss

SUBJECT	AGE	DATE OF CVA	CT FINDINGS	CLINICAL DIAGNOSIS
JC	68	10/91	N/A; (L) CVA, MCA Territory	Broca's Aphasia
BR	42	1/90	(L) f/t/p, involving basal ganglia	Broca's Aphasia
RH	56	6/80	N/A	Broca's Aphasia
DR	62	1982	(L) f/t/p, MCA territory	Broca's Aphasia
MA	59	6/90	(L) f/t/p, involving basal ganglia	Broca's Aphasia
OU	66	? & 12/90	#1: (L) parietal, internal capsule, anterior thalamus #2 (L) frontal	TCM
GdM	62	3/81	(L) CVA, MCA territory	Broca's Aphasia
EC	62	8/92	(L) frontal, deep to anterior horn	Broca's Aphasia
BZ	69	1/83	N/A; MCA Territory	Broca's Aphasia

Note: f/t/p=frontotemporoparietal lesion; N/A=not available; TCM=transcortical motor aphasia; MCA=middle cerebral artery

APPENDIX IV. CLINICAL AND CT DATA FOR APHASIC SUBJECTS

The following report is focused on individual subjects' performance on naming, repetition, auditory comprehension (e.g., 2-step commands and/or YES/NO reliability), and active/passive comprehension. These are reported WHENEVER AVAILABLE. CT reports are included, again if available. CT-based findings are provided, highlighting lesioned structures most associated with Broca's aphasia (Naeser, Palumbo, Helm-Estabrooks, Stiassny-Edner, & Albert, 1989). Specifically, the subcallosal fasciculus, associated with the initiation of language and the middle third of the periventricular white matter, associated with the motor aspects of language, are referred to whenever involved.

SUBJECTS

1. BZ is 69 years old with high school education. He suffered a left cerebrovascular accident (hereafter L CVA) in 1/83, with a residual Broca's-type aphasia. Testing in 1/84 showed his language profile to be characterized by moderate naming deficits, articulatory struggle, aprosodia, 4-word length phrases with mildly impaired sentence structure, comprehension spared on 2-step command level; all findings as reported from testing results in 1/84. CT is not available. The neurologic exam was consistent with an infarct in the L middle cerebral artery (MCA) distribution.

2. JC is 68 years old, high school educated, and sustained a L CVA in 10/91 with residual Broca's aphasia. The BDAE was administered in 4/92 and revealed naming to be moderately impaired, with literal paraphasias, repetition of single words at 50% accuracy, spontaneous utterances of 1-3 constituent length with consistent response latency and articulatory struggle noted. Auditory comprehension was assessed at 80% YES/NO reliability for abstract YES/NO questions. CT report and/or film were not available.

3. EC is 62 years old and went to college for 3 years. He suffered a L CVA in 8/92, with a residual Broca's aphasia. The WAB, given in 10/92, revealed the following: severe naming and repetition impairments, utterances intelligible only for "YES", "NO", minimal auditory comprehension deficits, and significant verbal apraxia were noted. CT findings were a left frontal infarct, extending deep to subcallosal fasciculus and to the middle third of the periventricular white matter (PVWM); all damage being in the middle cerebral artery distribution; PVWM change noted secondary to hypertensive microvascular disease.

4. BR is 42 years old, college educated, and sustained a L CVA in 1/90, with a residual Broca's aphasia. WAB results in 1/91 show severe naming and repetition impairments with persistent stereotypie "dada", severe verbal apraxia, and

auditory comprehension significantly impaired beyond the 2-step command and concrete YES/NO question levels. Performance on the active/passive comprehension test was 80% accurate for actives and 40% correct for passives. CT demonstrates a L frontotemporoparietal infarct involving the MCA territory with concommitant dilation of the ipsilateral ventricle and tissue loss. This lesion involves the middle third of the PVWM.

5. RH is 52 years old, high school educated, and suffered a L CVA in 1983, with a residual Broca's aphasia. BDAE findings in 3/92 revealed telegraphic speech, moderate anomia with verbal paraphasia, repetition good for high probability sentences but not for low, and active/passive test score was 90% accurate for actives and 20% for passives. Auditory comprehension was intact on the 2-step command level. Neuroimaging is not available.

6. DR is 62, high school educated, and suffered multiple L CVAs, first being in 5/82. Subsequent testing revealed Broca's aphasia characterized by moderate anomia, telegraphic speech of 1-3 words utterances, articulatory struggle, with relatively spared auditory comprehension. CT revealed a frontotemporoparietal infarct in the MCA distribution, with the lesion involving the subcallosal fasciculus, and middle third of the PVWM.

7. OU, who is 66 years old and high school educated, suffered two L CVAs, the first in 2/90 and last being in 12/90. WAB findings in 12/90 indicate an atypical TCM-like language profile, with repetition and confrontation naming being relatively strong, vis a vis empty, labored spontaneous conversation. Utterances were 3-4 words long, with limited incorrect usage of functor words, lack of substantive words, and pervasive articulatory struggle. Auditory comprehension was intact for abstract YES/NO questions, with difficulty noted on 2-step commands. CT in 12/90 demonstrated an old infarct involving the parietal lobe, genu of internal capsule, and anterior thalamus, and a new frontal infarct.

8. MA is a 59 year old man with a educational background including MBA and JD. He sustained a L CVA on 6/90, with a residual Broca's aphasia. Language findings based on the BDAE in 5/91 demonstrated severe anomia, verbal apraxia, difficulty on repetition, with a significant receptive component. CT revealed a L frontotemporoparietal infarct in the MCA territory, with extension to the basal ganglia.

9. GdM is 62 years old with high school education. He suffered L CVA in 3/81 with residual Broca's aphasia. Results from the BDAE in 8/85 indicate severe anomia, inability to repeat, and relatively spared auditory comprehension for 2-step commands, abstract YES/NO questions, and paragraph-length

stimuli. CT revealed a frontotemporoparietal infarct in the MCA territory, with extension deep to the subcallosal fasiculus and middle third of the PVWM.

APPENDIX V: ANOVA TABLES

TABLE A. APHASIC SUBJECTS, N=11; NORMAL SUBJECTS N=8

SOURCE	DF	F	P VALUE	MEAN SQUARE ERROR
GRP X HL X RU	1,15	7.463	<.05	.0009
GRP	1,15	10.22	<.05	.3652

TABLE B. APHASIC SUBJECTS, N=8; NORMAL SUBJECTS, N=8

SOURCE	DF	F	P VALUE	MEAN SQUARE ERROR
GRP X HL X RU	1,12	4.80	<.05	.0007
GRP	1,12	9.82	<.01	.2262

TABLE C. APHASIC SUBJECTS, N=11

SOURCE	DF	F	P VALUE	MEAN SQUARE ERROR
HL X RU	1,10	3.227	.1027	.0234
RU	1,10	.0008	.9779	.1017

TABLE D. NORMAL SUBJECTS, N=8

SOURCE	DF	F	P VALUE	MEAN SQUARE ERROR
HL X RU	1,7	7.782	.0269	.0119
RU	1,7	9.048	.0197	.0120

TABLE E. APHASIC SUBJECTS, N=8

SOURCE	DF	F	P VALUE	MEAN SQUARE ERROR
HL X RU	1,7	.729	.4215	.0181
RU	1,7	.218	.6547	.1042

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