RHYME PRIMING IN APHASIA

The role of phonology in lexical access

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March 1992

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements of the degree of Master of Science

ABSTRACT

The present experiment was conducted to explore the facilitory effects of rhyme in lexical processing in brain-damaged individuals. Normal subjects and non-fluent and fluent aphasic subjects performed auditory lexical decision and rhyme judgement tasks, in which prime-target pairs were phonologically related (either identical or rhyming) or unrelated. Results revealed rhyme facilitation of lexical decisions to real-word targets for normal and non-fluent aphasic subjects; for fluent aphasic subjects, results were equivocal. In the rhyme judgement task, facilitory effects of rhyme were found for all three groups with real-word targets. None of the groups showed clear rhyme facilitation effects with non-word targets in either task. Findings are discussed with reference to models of lexical access and the role of phonology in lexical processing in normal and aphasic populations.

RÉSUMÉ

Le but de la présente étude était d'examiner les effets de facilitation de rimes dans le traitement lexical de stimuli chez des populations cérébrolésés. Des sujets normaux, des sujets aphasiques fluents et des sujets aphasiques non fluents ont participé à une tâche de décision lexicale et une tâche de jugement de rime. Les stimuli étaient soit phonologiquement reliés (identiques ou qui rimaient), soit phonologiquement non reliés. Les décisions lexicales pour les vrais mots cibles ont été facilitées chez les sujets normaux et chez les sujets aphasiques non fluents. Quant aux sujets aphasiques fluents, les résultats se sont avérés ambigüs. Dans la tâche de jugement de rimes, des effets de facilitation de rimes ont été observés pour les mot cibles chez les trois groupes. Aucun des groupes n'a démontré des effets de facilitation de rimes pour les non-mots cibles, ni dans la tâche de décision lexicale et ce, ni dans la tâche de jugement de rimes. La discussion fait référence aux modèles d'accès lexical chez des populations normale et aphasiques.

ACKNOWLEDGEMENTS

I would like to express my appreciation to all those who helped this thesis take shape: to my professors of speech-language pathology, especially Dr. Gloria Waters and Dr. Donald Doehring, who contributed their expertise during the development of the study; to my fellow students in Room 62, who shared their insight, their experience and their liquid paper; to the secretaries of the School of Human Communication Disorders for mailing, faxing and photocopying; to Owen Sharman for his voice; to Laurie Ryan for her car, her computer and her moral support; to Gordon Arbess and Concetta Lisio for technical assistance; and to Hotel Lisio for their unfailing hospitality.

Special thanks go to all the subjects who volunteered their time to participate in this study, and to those speech-language pathologists who helped us to find subjects.

I would also like to thank my parents, who kept me going by asking, at least once a month, just when this thesis was going to be finished already.

My greatest debt of gratitude is to Shari Baum, my supervisor, who provided invaluable guidance, stimulating discussion and counselling above and beyond the call of duty.

This research was supported in part by a team grant from the Fonds FCAR du Québec.

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INTRODUCTION

Central to any comprehensive theory of language processing is a description of the structure and functions of the lexicon. This mental dictionary is the place where all words known to the individual are stored as prototypical representations in their various symbolic forms. Because words serve as our linguistic reference to the actual world, their organization and availability for use implicate all levels and modalities of language processing; lexical representations connect the acoustic codes of oral language and the visual codes of written language to our conceptual knowledge. Access to the lexicon is, therefore, essential to the comprehension and production of language in both visual and auditory modalities.

The importance of the lexicon to all aspects of language becomes apparent when studying lexical-semantic deficits in aphasia. Among the most common clinical observations across all subtypes of aphasia are word-finding difficulties (involving the retrieval of lexical items for production), and impaired auditory comprehension (involving perception of spoken words and access to their meanings). However, exactly what has been disrupted in such deficits is far from clear: Has the structure of the lexicon itself been disrupted? If so, have lexical items been lost or displaced? If not, is it the processes of storage and retrieval that have broken down? Is such breakdown systematic? Is it consistent across different types of aphasia? How can these problems be circumvented by various therapy techniques?

In order to address these issues, it is necessary to compare the language abilities of aphasic patients and normal subjects. Studies that explore the organization and use of language in the neurologically sound brain form the foundation for assessing the deviance of aphasic speech and language. In turn, the patterns of breakdown that emerge in aphasia carry implications for models of normal language-brain relationships.

In order to provide a theoretical and empirical background to the present study, the first section addresses the structure and function of the normal lexicon. Some of the models of lexical access that have had an impact on current research are described, and relevant research concerning the organization of and access to semantic and phonological information within the lexicon is reviewed. The second section presents a review of the relevant research on lexical processing in aphasic subjects, with reference to evidence from studies of normal subjects. Studies concerning semantic impairment and phonological impairment are reviewed. Implications of these impairments on models of the lexicon are discussed. In the final section of the introduction, the present study is introduced as it relates to previous research. Subsequent sections present the method used in the present experiment, the results of the study, and a discussion of its implications on the study of lexical access in both normal and aphasic subjects.

The Normal Lexicon

A lexical representation is assumed to include, at some level, all of the information that uniquely specifies a word: its acoustic, phonemic, and graphemic structures, its syntactic functions, its defining semantic characteristics, and perhaps a visual image. It is logical and intuitive to assume that items within the lexicon are organized in a manner to facilitate language processing. However, the way in which lexical items are organized so as to provide maximal efficiency of storage and retrieval remains controversial. Hypotheses must address several issues: What information is stored in the lexicon? How is it organized? What perceptual units are required to contact the lexicon? What are the mechanisms by which word recognition and lexical access are achieved? Do the processes involved in the lexical retrieval system operate independently or interactively? Many theories have been proposed which attempt to answer these questions; a few have been able to account for enough empirical results that they have endured.

Forster's (1976) "autonomous search" model is an example of a model in which top-down and bottom-up influences are strictly independent. Words are represented within a master lexicon, which, in receptive processing, can only be contacted through access files containing phonetic and graphemic information. Information from these access files is used to direct an active search, in order of frequency of occurrence, through the master lexicon. Once a lexical item has been identified, the lexicon passes information on to the syntactic processor, where it is organized into syntactic structures. Information from the syntactic processor is then passed to the message processor, where it is organized into conceptual structures. Syntactic and contextual information do not directly interact with sensory information, but instead are used as a post-access check. This serial chain of events is triggered automatically, independent of cognitive activity in the general processing system (GPS), which contains the store of world knowledge. Thus, Forster's model is primarily data-driven, and the different levels operate in a strictly autonomous fashion.

Like Forster, Morton (1969) developed a model of language processing in which the levels of information are arranged hierarchically, but Morton's was one of the first models to take into account the interaction of lower-level and higher-level sources of information during lexical access. In the "logogen" model (Morton, 1969) each word is represented by a specific place, or logogen, containing all the information (semantic, visual, and acoustic) relevant to that particular word. A logogen is activated as information, both sensory and contextual, matching that within the logogen is perceived. Information passively accumulates within each logogen, until it reaches a threshold level determined by the frequency of occurrence of the particular word. Since no active search is carried out among candidates, more than one logogen may be activated at a time. However, activation decays rapidly if it is not maintained by continued processing.

In the late seventies and early eighties, the focus of word recognition studies shifted from written to spoken language. With this shift in perspective, the nature of acoustic/phonetic processing came under more intense scrutiny, and spawned two models of word recognition which placed more emphasis on the temporal nature of speech processing. Unlike Morton's highly interactive, and Forster's strictly autonomous models, Marslen-Wilson & Welsh's (1978) active direct access model, which later became known as "cohort" theory, has both autonomous and interactive elements: In the first stage, incoming acoustic-phonetic information is used to activate a cohort of words sharing word-initial information; in the second stage, sensory input and contextual constraints interact to narrow down the cohort until only one word candidate is isolated, that is, recognized. Cohort theory is primarily concerned with auditory word recognition, and emphasizes the temporal perception of speech. Words are recognized from beginning to end; the cohort is reduced as more of the word is heard and fewer word candidates match the speech signal.

McClelland & Elman's (1984, 1986) interactive-activation or TRACE theory adapted cohort theory (Marslen-Wilson & Welsh, 1978), attempting to overcome its restrictions by creating a more interactive model. The TRACE model consists of "nodes" organized into a hierarchical structure of features, phonemes, and words. Like Morton's logogens, these nodes are activated up to a threshold level by the perception of matching stimuli. However, while Morton allows for the activation of more than one node simultaneously, TRACE theory states that activated nodes inhibit the activation of other nodes within the same level. Nodes at lower levels excite connected nodes at higher levels: combined features excite phonemes which combine to excite words. The entire network of nodes activated by a given stimulus is termed the "trace." Excitation also flows in the opposite direction as feedback, a mechanism which allows early-occurring, lower-level information to remain activated and thus maintain its influence on higher levels. This system of excitatory feedback creates a highly interactive model of lexical access.

While the above models deal primarily with the mechanisms by which the lexicon is accessed, Collins & Loftus (1975) developed a theory of activation within the lexicon. According to the spreading-activation theory of lexical access, concepts, or words, are represented as nodes in a network, and these nodes are linked by relationships between concepts. The lexicon consists of two networks: a conceptual one in which concept nodes are linked by their semantic relationships (e.g. superordinate, subordinate, modifier), and a "lexical" network in which lexical representations, or names, of concepts are linked by their phonemic and orthographic relationships. When nodes are activated by the perception of their names in spoken or written language, for example, this activation spreads automatically among contiguous nodes within the network and between lexical nodes and their corresponding concept nodes. Although only one node may be the source of activation, many connected nodes may become activated at the same time. Activation is released from the source node as long as it is being processed, but once processing stops, the activation naturally decays.

Posner & Snyder (1975) elaborated spreading activation theory to involve two separate processes: automatic activation, occurring without intention and independent of other cognitive processes, and conscious processing, involving intentional use of limited-capacity resources. It is now apparent that different tasks demand different types of processing, and that this must be considered when generalizing results from studies of both normal and aphasic subjects to models of lexical access.

Semantic Studies

Many of the early studies concerning the semantic structure of the lexicon involved tasks such as semantic categorization of words, the production of category exemplars, or judging semantic relatedness, which require overt semantic decision-making. Tasks such as these, that deliberately focus the subjects' attention on semantic relations, have been criticized as artificial, reflecting "conscious," not "automatic" processing of language. Instead, critics have proposed more "on-line" tasks, in which the data of interest are taken from processes not under the subject's volitional control. Such tasks are assumed to reflect more closely the actual structure and processes of the lexicon.

One such on-line procedure that has become common in studies of the lexicon is the priming paradigm. In priming tasks, the "prime" stimulus is followed by a "target" or "probe" stimulus, which is the focus of the task. Response times to prime-target pairs which are related along the variable of interest are compared to response times to unrelated prime-target pairs. "Priming" occurs when the recognition of a target word, measured by the latency of response to that word, is facilitated (i.e. speeded up) by the prior presentation of a related word. According to spreading-activation theory, once a word is activated, the activation spreads to related words to which it is linked in the network. If a related word is subsequently presented, it will already be partially activated (or "primed"), and will thus require less time to reach its threshold of activation. Priming principles can be adapted to a number of different experimental tasks, including category exemplar production, colour-naming (Stroop) tasks, pronunciation (naming), and lexical decision tasks.

In lexical decision tasks, subjects are required to judge whether or not the target stimulus is a real word. The time it takes to do so is interpreted as a measure of how quickly the word is recognized. Response data to non-word targets are not interpreted in the same way, since non-words have no meaning and, thus, no representation in a semantic lexicon. It is assumed that "no" responses can be made only after the lexicon has been thoroughly searched and no lexical item has been found to match the stimulus. An advantage of the lexical decision task is that it ensures that the lexicon is being accessed, whereas tasks such as same-different judgements and pronunciation may be carried out on the basis of sensory information alone. Another advantage of lexical decision over naming is that it can be conducted in the visual or auditory modality. However, most semantic priming studies, such as those described in the following paragraphs, have been carried out with written stimuli.

One of the earliest studies to provide support for spreading-activation theory was a visual lexical decision experiment conducted by Meyer & Schvaneveldt in 1971. A pair of printed letter strings was presented, in which the letter strings were either related according to association norms (e.g. BREAD-BUTTER, NURSE-DOCTOR), or unrelated (e.g. BREAD-NURSE). If both strings were words, subjects were to respond "yes"; if either or both were nonwords, subjects were to respond "no". Meyer & Schvaneveldt found that associated word pairs were responded to more quickly than unassociated word pairs; that is, their access was facilitated. According to the logic of priming, the processing of the prime facilitated the subsequent processing of a related target (assuming the pairs, though presented simultaneously, were processed serially).

Meyer & Schvaneveldt used associatively related stimuli, which are defined not by hierarchical semantic relationships, but by the frequency with which two words are used or perceived together. While associative relationships are often semantic in nature, they may also be syntactic, or determined by some other factor. Fischler (1977) extended Meyer & Schvaneveldt 's results in an experiment which included, in addition to associatively related pairs, pairs which were semantically related, but not normatively associated. Semantically related pairs provided greater facilitation than did associatively related pairs, relative to unrelated pairs. Fischler's results suggested that associative priming effects are due to semantic relatedness rather than "accidents of contiguity," supporting the notion of a semantic network. Nevertheless, experimenters continue to use associative norms as a measure of semantic relatedness, since they are empirically relevant. Moreover, the degree of association can be quantified by the norms.

The strength of association has been found to influence results of semantic priming studies. In a category judgement task, Lorch (1982) defined strength of association as the dominance of a category exemplar. The category name was presented as the prime, and an exemplar as the target. Responses to strongly associated category exemplars (e.g. ANIMAL-CAT) were significantly faster than to weakly associated exemplars (e.g. ANIMAL-BULL). Furthermore, "no" responses were significantly slower to highly associated non-exemplars (e.g. ANIMAL-CRACKER) than to unassociated non-exemplars (e.g. ANIMAL-BOSTON). Thus, prime-target associations slowed, or inhibited, negative responses, as well as facilitating positive responses. In a separate task, naming of high-dominance category exemplars was also facilitated more than low-dominance exemplars, relative to exemplars preceded by a neutral prime (the word BLANK). In a visual lexical decision task, deGroot, Tomassen & Hudson (1982) also showed that responses to strongly associated words were facilitated, while responses to unrelated targets were inhibited; lexical decisions to weakly associated words were neither facilitated nor inhibited, relative to a neutral non-linguistic prime (a row of crosses).

Depth of automatic spreading activation (ASA) has also been explored. According to Collins and Loftus (1975), "the spread of activation constantly expands, first to all the nodes linked to the first node, then to all the nodes linked to each of these nodes, and so on...to some unspecified depth" (pp. 408-409). DeGroot (1983) set out to specify this depth using related, unrelated, and "mediated" Dutch word pairs in a visual lexical decision task. Mediated pairs were formed from the first and third members of word triplets in which the first and second, and second and third, but not the first and third words were associated (e.g. KLUIF-HOND-BLAFFEN; in English, bone-dog-bark). These pairs were thus "mediated" by the absent middle word to which both members of the pair were related.

As in deGroot et al. (1982), facilitation was found for associatively related pairs and inhibition for unrelated pairs, relative to the neutral prime BLANCO (blank). No effect was found for mediated pairs, and thus no support for spreading activation beyond one link in the semantic network. Balota & Lorch (1986) attempted to replicate deGroot's study using more strictly controlled stimuli and varying the type of task. Like deGroot (1983), they found very little evidence for multiple-step ASA in a lexical decision task: related pairs were facilitated, but there was no significant difference in reaction time among targets preceded by mediated, unrelated, or neutral primes.

However, Balota & Lorch (1986) did find facilitation of mediated pairs in a naming task. This constituted the first empirical support for multiple-step ASA. Spreading activation theory predicts that activation decreases with the distance it travels (and the time it takes to travel that distance). In addition, activation is assumed to be divided among the number of nodes to which it spreads, and the number of nodes activated increases exponentially with each step of spreading activation (Collins & Loftus, 1975). Therefore, since mediated words are twice as far apart as related words, and one step removed, they should result in longer reaction times. This is what Balota & Lorch (1986) found; direct semantic associates (one-step ASA) resulted in greater facilitation than mediated associates (multiple-step ASA).

Balota & Lorch (1986) attributed the different results obtained in the two tasks to a tendency of subjects to search for a strong meaningful relationship between the prime and the target. Such a strategy would take place after lexical access (and after naming), but before the lexical decision is made. This extra stage would slow reaction times to unrelated and mediated targets, but not related targets, for which such a relationship would be found immediately. This inhibition would be offset to some degree for mediated pairs, by facilitation of automatic spreading activation from the mediating word, resulting in a cancelling out of facilitory and inhibitory effects.

Strong evidence for the existence of semantic or associative links in the lexicon comes from priming studies. Although any activation spreading further than one node is apparently not strong enough to be detected by a lexical decision task, the basic tenets of Collins & Loftus' (1975) spreading activation theory are upheld for a semantic lexicon. Further studies have investigated the existence of similar phonological lexical links.

Phonological Studies

If phonological links exist in the lexicon, what is the nature of such links? Which representations, graphemic or phonemic or both, determine the structure of the lexicon? Are words organized according to their initial phonemes, like a phonological dictionary, or are words arranged according to rhyming relationships? Where would this phonological information be stored within a model of language processing?

Many of the early studies concerning phonological connections in the lexicon were conducted visually, and focussed on the respective roles played by orthographic and phonologic encoding in lexical access. Some of these experiments provided important early evidence for rhyming relationships within the lexicon, and also have implications for models of lexical access.

Meyer, Schvaneveldt & Ruddy (1974) set out to explore the processes involved in written word identification: whether lexical access occurs directly from a graphemic code, or the stimulus must first be phonemically recoded, or both codes become available at once. In a visual lexical decision experiment, prime-target pairs, presented simultaneously, were either phonologically similar (rhyming) and graphemically similar (e.g. BRIBE-TRIBE), graphemically similar but phonologically dissimilar (e.g. COUCH-TOUCH), or phonologically and graphemically dissimilar (formed by interchanging members from different stimulus pairs, e.g. BRIBE-TOUCH). Graphemically similar word/non-word, non-word/word, and non-word/non-word pairs were also included with their dissimilar controls. Reaction times to rhyming graphemically similar word/word pairs (positive responses) were faster than responses to unrelated pairs (although the effect was not significant), but reaction times to pairs that were only graphemically similar were inhibited relative to unrelated controls. Thus, at least some of the facilitation of phonologically and graphemically similar pairs appears to have been due to the rhyming relationship alone. No significant differences were found between conditions of negative (word/non-word, non-word/word, and non-word/non-word) pairs.

Meyer et al. (1974) proposed the encoding-bias model to explain these results. According to this model, phonemic recoding occurs before lexical decision, and the grapheme-phoneme correspondence (GPC) rules used to recode the first word of the pair will bias the GPC rules used for the second word. This accounts for the inhibition of graphemically similar, but phonemically dissimilar pairs.

Hillinger (1980) conducted both visual and cross-modal lexical decision experiments in order to test the encoding-bias model. He hypothesized that if priming occurs as a result of a grapheme-to-phoneme encoding bias, the auditory presentation of the prime would eliminate the phonological recoding stage (since the prime's phonological code would be presented directly), and thus eliminate any facilitory effects of rhyming and any inhibitory effects of non-rhyming. If rhyme effects were found, they would have to explained by a mechanism other than a grapheme-to-phoneme recoding bias.

In both visual and cross-modal paradigms, Hillinger found a strong facilitory effect for graphemically and phonologically similar pairs, but, unlike Meyer et al., no inhibition for graphemically similar, non-rhyming pairs. In order to ensure that the facilitory effects did not result from graphemic similarity, Hillinger added to the visual task a phonologically similar but graphemically dissimilar condition (e.g. EIGHT-MATE), for which no facilitation should occur, according to the encoding bias model, because the two words use different GPC rules. A facilitory effect was found for these pairs, which was as great as the facilitation found for graphemically and phonologically similar pairs (e.g. LATE-MATE). These results clearly do not support the encoding-bias hypothesis. Instead, Hillinger proposed that rhyming facilitation occurs by means similar to semantic facililation: spreading activation within a phonological file (following Forster's (1976) model) or along dimensions of physical similarity within the lexicon (following Morton's (1969) model).

Since access to this "file" is sufficient to make word/non-word decisions, it must contain lexical information. The simplest conception of such a file is a phonological lexicon containing only lexical items (since the number of non-lexical items that could be included is virtually limitless). If non-words have no representations, then their presentation should not facilitate lexical decisions. This would account for the lack of priming found by both Meyer et al. (1974) and Hillinger (1980), for rhyming non-word/word pairs (e.g. JATE-MATE) and rhyming word/non-word pairs (e.g. GATE-JATE).

Although the rhyme effect found by Hillinger (1980) was equally large in both modality conditions (visual and cross-modal), reaction times to visually presented targets were longer when preceded by auditory primes than when preceded by visual primes, suggesting that the within-modality task was easier than the cross-modality task. This "modality effect" was interpreted by Hillinger as evidence for separate phonological and graphemic representations, as in Forster's (1976) autonomous search model. Rhyme facilitation has also been found in other tasks. Lupker & Williams (1989) found that naming of both words and pictures was facilitated following the presentation of a rhyming prime. Hudson & Tanenhaus (1985) found rhyme priming when the prime was embedded within an auditorily presented sentence and the target (which completed the sentence and rhymed with the prime) was presented visually. Facilitation occurred whether the prime occurred in the first or second clause of the sentence, but was greater when the prime and target were in the same clause. These findings suggest that phonological codes are activated and available for use for several seconds, but that this activation gradually decays, as suggested by Collins & Loftus (1975).

Tanenhaus, Flanigan & Seidenberg (1980) proposed that both orthographic and phonological codes become available automatically. They conducted a colour-naming (Stroop) task, in which the subject was required to name the colour of ink in which the target was printed. In this type of task, priming draws attention to an aspect of the target, whether phonological or semantic, that is irrelevant to the response requirements (colour-naming), and thus actually interferes with the response. Colour-naming interference was found for orthographically similar only (e.g. BEAD-BREAD), phonologically similar only (e.g. BED-BREAD), and orthographically and phonologically similar (e.g. DEAD-BREAD) pairs relative to unrelated pairs, whether the prime was presented auditorily or visually. None of the related conditions were significantly different from each other in either modality, lending support to the hypothesis that both orthographic and phonological codes are automatically activated, since both orthographic similarity and rhyming result in priming.

Just as auditory codes have been found to be activated in visual word recognition, visual codes have been found to play a role in auditory word recognition. Rhyme detection (Seidenberg & Tanenhaus, 1979) and rhyme monitoring (Donnenwerth-Nolan, Tanenhaus & Seidenberg, 1981) were facilitated for orthographically similar rhymes relative to orthographically dissimilar rhymes. Thus orthography appears to become available automatically in auditory tasks, even when it interferes with the task demands. These results are inconsistent with Forster's model (1976), in which graphemic and phonological codes are stored in separate files, whose access depends on the modality of the stimulus. They are consistent, however, with Morton's

(1969) and Collins & Loftus' (1975) models, in which both types of information are stored within the same representation.

Purely auditory tasks have also revealed facilitory effects of rhyming. Burton (in press) investigated rhyme priming in an auditory lexical decision task, predicting, as in Hillinger (1980), a facilitory effect of rhyming word primes, but no facilitation from rhyming non-word primes, since non-words are not represented in the lexicon. Facilitation was found, as predicted, for identical and rhyming word primes relative to unrelated word primes. However, non-word primes were also found to facilitate lexical decisions; non-word targets were also facilitated by identical primes, and rhyming word and non-word primes. Burton interpreted these unexpected non-word priming results as due to a sublexical physical matching procedure, rather than spreading activation within a phonological lexicon.

The evidence of rhyme facilitation in visual, cross-modal, and auditory word recognition experiments, as outlined above, supports the existence of a lexical structure based on phonological similarity. Graphemic similarity also seems to facilitate word recognition, but whether graphemic and phonological codes are stored in the same or separate files is not clear. Evidence of non-word rhyme priming (e.g. Burton, in press) suggests that phonological facilitation may also occur at a sub-lexical level. While the above studies dealt specifically with rhyme relationships, other phonological similarities may also serve to connect lexical items.

The growing emphasis on auditory language processing, and the emergence of cohort theory (Marslen-Wilson & Welsh, 1978) led several researchers interested in the role of phonology in lexical access to focus on word-initial rather than word-final (i.e. rhyming) relationships. In the studies that led to the formation of cohort theory, Marslen-Wilson & Tyler (1975) investigated the time-course of auditory word processing using auditory monitoring tasks. They found that subjects monitoring a list of words could identify monosyllabic words about 300 msec after their onset, and about 100 msec before their offset. In a subsequent experiment (Marslen-Wilson & Welsh, 1978) subjects were required to shadow (repeat immediately after presentation) auditorily presented passages of prose containing mispronounced three-syllable words. The presence of phonemically restored mispronunciations was interpreted as evidence that the recognition of a word does not necessitate analyzing all of the phonetic input. Furthermore, if word recognition proceeds according to a left-to-right analysis, mispronunciations in the third syllable of a word should have been more frequently restored than mispronunciations in the first syllable, since the word was more likely to have been identified by the third syllable. Results showed that almost half of the mispronunciations were restored, but no significant difference in restoration rate was found between mispronunciations occurring in the first syllable and those in the third syllable. Thus, although there was support for the concept of word recognition occurring as the result of a diminishing cohort of candidates, the actual phonological information that might activate such a cohort is not clear.

In 1980 Grosjean developed a different experimental paradigm--gating--to analyze the on-going processing of spoken language. In gating tasks, part of an auditory stimulus is presented repeatedly, each time increasing the amount of the word presented (e.g. N-, NU-, NUR-, NURSE). Subjects are asked after each presentation to try to identify the word. Grosjean found that, on average, one-syllable words were identifiable when only 289 msec of the word was presented, two-syllable words were identified after 306 msec, and three-syllable words after 406 msec. Thus, the longer the word, the longer the isolation time. Grosjean's results provided support for cohort theory's claim that a word is recognized as soon as enough of the incoming stimulus is presented to differentiate it from all other words. In fact, Grosjean's results were remarkably consistent with the results reported by Marslen-Wilson & Tyler (1975).

Salasoo & Pisoni (1985) also conducted a gating task, using both forward-gated (from the beginning) and backward-gated (from the end) words to test whether initial phonological information is necessary to identify words. Forward-gated words required shorter durations to be identified, and resulted in fewer incorrect candidates being proposed, than did backward-gated words, supporting Grosjean's (1980) results. However, word identification was still possible with backward-gated words before the beginning of the word was identified, suggesting that word-initial information is not critical, and that word recognition, for these words at least, must be occurring by some mechanism other than activation of a word-initial cohort.

The role of word onsets has also been investigated by means of priming paradigms. In an auditory lexical decision task, Jakimik, Cole & Rudnicky (1985) investigated the role of orthography in auditory lexical access. They found that one-syllable word targets derived from the first syllable of their respective two- or three-syllable primes (e.g. NAPKIN-NAP) were facilitated relative to their unrelated control word targets. However, this effect did not hold for pairs in which the target was phonologically, but not orthographically similar to its prime (e.g. CHOCOLATE-CHALK), nor for pairs in which targets were orthographically but not phonologically similar to their primes (e.g. FIGHTER-FIG). Similarly, non-words were facilitated only if they shared sound and spelling with their primes (e.g. FAMILY-FAM), but not if they shared sound alone (e.g. PRECIOUS-PRESH). (No graphemically similar/phonologically dissimilar pairs were possible with non-words, since non-words cannot have irregular spellings.) Not only does this experiment illustrate the use of graphemic codes in auditory word recognition, but it also suggests that rhyming is not the only phonological relationship that can cause priming. Word-initial information, or perhaps shared stressed syllables, may also provide facilitation, but apparently only if the shared phonological information is also graphemically similar.

Slowiaczek & Pisoni (1986) applied the logic of cohort theory to an auditory lexical decision task. They predicted that a target would be facilitated after a prime sharing word-initial phonological information because the target would retain residual activation as a member of the prime's cohort and that, furthermore, the amount of this facilitation would increase as a function of the amount of phonological overlap between a prime and its target. They compared identical prime-target pairs to pairs sharing three initial phonemes (e.g. PRICE-PRIDE), two initial phonemes (e.g. PRONE-PRIDE), and one initial phoneme (e.g. PLAN-PRIDE). Both word and non-word primes were used since cohort theory predicts the activation of a cohort from acoustic-phonetic information, regardless of its lexical status. Results revealed that identical primes provided significant facilitation for targets relative to other prime conditions, but that phonological similarity did not otherwise facilitate the latency of target processing, for either word or non-word targets. In fact, there was some evidence of inhibition as phonological similarity increased. Thus, cohort theory was not supported. Slowiaczek & Pisoni suggested that the lack of phonological priming may be due to an insufficient degree of phonological overlap. According to Slowiaczek & Pisoni (1986), in rhyme priming the overlap is at least 50%, usually 66% or more, and in the Jakimik et al. (1985) study discussed earlier, the entire target appeared in the prime (e.g. NAPKIN-NAP). However, the amount of phonological overlap cannot fully account for Slowiaczek & Pisoni's results, since no priming was shown even when the prime and target shared 75% of their phonological information (as in PRICE-PRIDE).

In a later study, Slowiaczek, Nusbaum & Pisoni (1987) addressed the concern that the lack of priming in Slowiaczek & Pisoni (1986) could have resulted from the response requirements of the lexical decision paradigm drawing attention away from the phonological similarity between primes and targets. In a perceptual identification priming study, subjects were required to identify isolated words masked by white noise. Primes were unmasked and their phonological overlap with targets was varied in the same way as in Slowiaczek & Pisoni (1986): identical, unrelated, or with three, two, or one overlapping phoneme. In this experiment, facilitation was found to increase as a function of phonological overlap, although not in a linear fashion. There was no significant difference between unrelated pairs and pairs sharing one phoneme, nor between pairs sharing two and three phonemes, but identical pairs were significantly faster than pairs in all other conditions, and pairs sharing two phonemes were significantly faster than pairs sharing only one phoneme. A similar, but weaker, effect was found for non-word primes.

Although these results support cohort theory, the experimenters found similar facilitory effects as phonological overlap increased from the ends of words (e.g. COLD-FIND, COLD-FILLED, COLD-GOLD, COLD-COLD). It is interesting to note that, for these pairs, there was no significant difference between unrelated and one-phoneme overlaps pairs, nor between pairs sharing one and two phonemes, nor pairs sharing three phonemes and identical pairs, but there was a significant difference between pairs sharing two final phonemes (COLD-FILLED) and those sharing three final phonemes (COLD-GOLD). These two types of pairs represent the difference between non-rhyming and rhyming pairs. Slowiaczek et al. (1987) concluded that "the only advantage for word-initial information in speech perception may simply be a temporal one: The beginnings of words are heard first and therefore receive the most processing. As a consequence, word beginnings may have the earliest impact on the recognition process" (p. 74).

The studies reviewed above show robust evidence for the existence of rhyme relationships between words, but there is also some evidence, although less consistent, supporting links between words sharing word-initial information. Phonological priming between words suggests that a phonological lexicon similar to the semantic lexicon may exist; however, results demonstrating priming with non-words bring up the possibility that phonological priming takes place at a sublexical level. Wherever it exerts its effect, one must also consider how phonological information interacts with semantic information.

Semantic and Phonological Interaction

Given the evidence supporting both semantic and phonological connections within the lexicon, it becomes important for any theory of word recognition and lexical access to deal with how the two types of representations are coordinated, and the extent to which they interact. According to Forster (1976), the two types of information do not interact during lexical access; the lexical and semantic files are completely autonomous. By contrast, in Morton's (1969) logogen model, semantic and phonological information interact from the initial stages of word recognition.

Cohort theory (Marslen-Wilson & Welsh, 1978) predicts the influence of syntactic and semantic constraints in word recognition, but only after the phonological input has exerted its initial, dominant influence.

Loftus & Cole (1974) proposed a dictionary-network model in which semantic and lexical information are represented in two separate structures: a complex network for semantic information and an alphabetical dictionary listing for lexical information. In a category exemplar naming task, subjects were presented a category name and two cues, one semantic and one graphemic (e.g. FRUIT-YELLOW-B) and were required to name a member of that category that satisfied both criteria (i.e. a yellow fruit that begins with "b"). Subjects responded faster if the adjective cue was presented before the letter cue, than if the letter cue was presented first. Loftus & Cole reasoned that the differences in response times resulted from the time taken to switch from one lexicon to the other. The category (e.g. FRUIT) was presented first, and would therefore have been accessed first within the semantic network; if the adjective was then presented, it would have been used to direct the lexical search within the semantic network to the subset of fruit that are yellow; the following letter cue would have redirected the subject to the lexical dictionary to look up a yellow fruit beginning with "b". If, however, the letter cue was presented immediately after the category name, the subject had to switch from the semantic network to the lexical dictionary to look up all fruit beginning with "b", then back to the semantic network to find one that is yellow.

Lupker & Williams (1989) also hypothesized separate semantic and lexical memory stores that must be accessed in serial, depending on the stimuli and the task demands. Both picture stimuli, assumed to directly access semantic memory, and word stimuli, assumed to directly access lexical memory, were used in categorization (semantic) and naming (lexical) tasks. Longer reaction times to name pictures than to name words supported the concept of separate semantic and lexical stores, since naming pictures would involve a shift from the semantic to the lexical network. In addition, naming of both word and picture targets was facilitated following naming of a rhyming word or picture, since naming necessitates access to lexical memory where rhyming exerts its effect. Categorization of words, but not pictures, was also facilitated following naming of a rhyming word or picture, since categorization of words involves lexical and semantic memory, while categorization of pictures involves only semantic memory, and thus allows no locus for rhyming to exert an effect.

Donnenwerth-Nolan et al. (1981) included a semantic factor in an auditory rhyme monitoring task, in order to ensure that word meanings were being accessed during the task. A cue word (e.g. KITE) was presented, followed by a list of three words containing a rhyming target (e.g. (VEST-BITE-TOLD). In half of the trials, the word immediately preceding the target within the target list was semantically similar to the target (e.g. CHEW-BITE-TOLD). As in their previous experiments, orthographically similar rhymes were detected more quickly than orthographically dissimilar rhymes, but this effect was not as great as the semantic effect: rhyme monitoring latencies were significantly faster when the target was preceded by a semantically related prime. Thus, both semantic and phonological information influenced decisions within the same trial.

If it is true that phonological and semantic information are represented separately, as in Collins & Loftus' (1975) network model, the question remains: How do these two networks interact? Much of our information about the interaction of semantics and phonology comes from mediated priming studies involving both semantic and phonological relationships. McNamara & Healy (1988) used "self-paced reading" and visual lexical decision tasks to investigate semantic priming, phonological priming, and mediated priming from the semantic to the phonological lexicon. The experiment included three experimental conditions, in order to test each link: semantic (e.g. LIGHT-LAMP), phonological (LAMP-DAMP), mediated (e.g. LIGHT-DAMP), and three control conditions formed by mixing up the word sets for each condition. Word-nonword pairs were also included.

The reading task showed reliable facilitation for semantically related and rhyming pairs, but no effect for mediated pairs. In the lexical decision task, reaction times indicated that, relative to their respective control conditions, semantically related pairs were facilitated, rhyming pairs were not (although the trend was in the expected direction), and mediated pairs were inhibited. In addition, the error rate in the mediated condition was significantly greater than in its control condition. Subsequent replications were undertaken to compare the type of task and the presence or absence of non-words among the stimuli; in all of these, there was either no effect or an inhibitory effect of mediated priming.

The absence of mediated priming enabled McNamara & Healy (1988) to conclude that activation does not spread automatically from a semantic to a lexical network, a conclusion that favours autonomous models over interactive models. However, semantic and rhyming effects were not reliable across the different tasks: rhyme priming effects were not found at all in the lexical decision tasks, and were unreliable in the reading tasks when only words were included among the stimuli. In addition, semantic priming of lexical decisions was only reliable when non-words were not included among the stimuli, a manipulation that renders the purpose of the task questionable. Without robust effects of semantic and rhyme priming, upon which mediated priming depends, it is difficult to draw conclusions about the presence or absence of mediated priming. As well, the direction of mediated priming must be considered. Whereas McNamara & Healy did not find the spread of activation from the semantic to the phonological network, activation may spread from a phonological to a semantic network. In fact, this would appear to be more useful for speech perception in real-language processing since the perception of speech codes is the means by which we access word meanings.

Marslen-Wilson and Zwitserlood (1989) explored the spread of activation from phonological to semantic stores. Their purpose was to compare the facilitory effects of word onsets and rhymes, using cross-modal lexical decision tasks with Dutch stimuli. In an unpublished experiment (Marslen-Wilson, Brown & Zwitserlood, 1989) one of two words which shared a large initial overlap (e.g. KAPITEIN and KAPITAAL; English "captain" and "capital", respectively) was presented auditorily as the prime. A target semantically related to one of the two primes (e.g. BOOT or GELD; "boat" or "money") was then presented visually. When the target was presented in the middle of the presentation of the spoken prime (KAPI:), when either prime was still possible, both targets were facilitated. However, when the target was presented at the end of the prime, only the target associated to the prime that was actually presented was facilitated. Thus, words that were phonologically related by shared word-initial information were activated simultaneously. In the cohort model, both words would be activated as members of the cohort of words beginning with "kapi".

In a subsequent experiment, Marslen-Wilson & Zwitserlood (1989) tested the hypothesis that it is the amount of matching phonological information between the input and the activated word that is important, regardless of whether it comes at the beginning or end of the word, and regardless of the lexical status of the input. In a similar cross-modal lexical decision task, rhyming words and non-words were used as mediated primes. For example, HONING (honey) served as a semantic prime for BIJ (bee), while WONING (dwelling) served as a mediated word prime and FONING as a mediated non-word prime (both being phonemically related to HONING, which is semantically related to BIJ). A significant semantic priming effect was found; however, reaction times to both word and non-word mediated pairs, although faster than reaction times to their respective unrelated pairs, were not significantly so.

Marslen-Wilson & Zwitserlood (1989) interpreted the results of these two experiments as support for the hypothesis that word recognition occurs in a specific left-to-right direction: "Primes that do not share word onsets with the relevant lexical form representations are much less effective than primes that do--whether compared with the complete match conditions in this experiment or with the word-initial partial primes used in earlier research" (p. 580). Marslen-Wilson & Zwitserlood apparently see their "complete match" condition (e.g. HONING-BIJ) as a mediated priming condition comparable to WONING-BIJ, except that it shares word-initial information (i.e. is identical to) the mediating lexical representation. A simpler perspective is that HONING is directly semantically related to BIJ and, therefore, would be expected to provide greater facilitation than an indirectly related word such as WONING. On the other hand, the partial prime KAPI: may be interpreted as a mediated condition (with KAPITEIN mediating to BOOT, for example). However, a partial prime such as KAPI: is not comparable to a complete prime such as WONING, given the assumption of cohort theory that competitors drop out of the cohort as soon as they become incompatible with the incoming stimulus. It would be more appropriate to compare the mediated condition of KAPITEIN-GELD to the mediated condition of WONING-BIJ: neither of these conditions resulted in mediated priming.

Mediated priming experiments have also used pronunciation paradigms with non-word primes or non-word targets. In several experiments, Rosson (1983) investigated the hypothesis that pseudowords are pronounced in accordance with the grapheme-phoneme correspondence rules used in similar real words. In a mediated priming paradigm, subjects were required to pronounce both primes and targets. Related word primes (e.g. LAMB-SHEEP) were compared to unrelated word primes (e.g. LURE-SHEEP), and related pseudoword primes (e.g. FAMB-SHEEP) were compared to unrelated pseudoword primes (e.g. FURE-SHEEP). Both related words and pseudowords were facilitated relative to their respective unrelated control conditions. In fact, although reaction times were faster for words than pseudowords, the amount of facilitation was almost the same, despite the fact that LAMB-SHEEP is a direct semantic relationship, while FAMB-SHEEP is an indirect relationship mediated by "lamb".

While this experiment tested the link between phonological and semantic networks, another of Rosson's (1983) experiments tested the link from a semantic to a phonological network. She compared the pronunciation latencies of pseudoword targets (e.g. DEPPER) preceded by related (e.g. SALT) and unrelated (e.g. SELL) word primes. No significant difference was found between the two conditions, although there was a trend in the expected direction. These apparently contradictory results could be interpreted as evidence that activation is able to spread from phonological representations to semantic representations, but not in the opposite direction. However, because these results involve non-words, the phonological relationship tested is presumably at a sub-lexical level, not a lexical level.

A further experiment by Rosson (1983) involved pronunciation of ambiguously spelled pseudowords as a means of controlling the potential facilitory effect of visual similarity on pronunciation. For example, the pseudoword LOUCH could be pronounced to rhyme with COUCH or TOUCH, and it shares an equal amount of visual similarity to both. As expected, subjects showed a bias toward the "regular", more common pronunciation for 80% of the pseudowords. (In this case, LOUCH would be pronounced to rhyme with COUCH.) However, this tendency occurred significantly (14%) less often when pseudowords were preceded by a prime word that biased toward the irregular pronunciation (e.g. FEEL-LOUCH vs SOFA-LOUCH). These results offer some support for the spread of activation from semantic to phonologic representations. As Rosson suggested, these results pose problems for models such as cohort, in which the input is processed from left to right, because pronunciations in two of the three experiments were based on the similarity between the pseudoword and a real word (mediating) in all <u>but</u> the initial phoneme. According to cohort theory, the non-words should have consistently been pronounced according to the most common grapheme-to-phoneme correspondence rules, and this pronunciation should not have been influenced by the rhyming relationship between the target and the mediating word (TOUCH or COUCH).

Milberg, Blumstein & Dworetzky (1988a) also studied the spread of activation from the phonological to the semantic network using non-word rhyme primes. Semantic and mediated conditions similar to those used by Rosson, were compared in an auditory lexical decision task. Semantically related word primes (e.g. CAT-DOG) and non-word mediated primes that rhymed with the mediating semantic prime and differed from it by either one phonetic feature (e.g. GAT-DOG) or more than one phonetic feature (e.g. WAT-DOG) were compared to unrelated word primes (e.g. TABLE-DOG). Facilitation of lexical decisions was found for both semantically related pairs and mediated pairs relative to unrelated pairs. Direct semantic primes resulted in greater facilitation than mediated primes differing by one feature from the semantic prime, which in turn resulted in greater facilitation than primes differing by more than one feature from the semantic prime. Thus, the amount of priming depended on the prime's phonological distance from a directly related semantic prime. Like Rosson's (1983) pronunciation results, these results are inconsistent with models in which lexical access depends on the perception of word-initial phonological information.

In a replication of the Milberg et al. (1988a) study, Burton (in press) extended the stimulus set to include word mediated primes (e.g. BAT-DOG). Despite consistent facilitory effects of semantic and rhyme priming, Burton failed to find any effect of mediated pairs, whether mediated primes were words or nonwords. Burton hypothesized that rhyme priming occurs during an earlier, stimulus-encoding stage and associative priming during a lexical processing stage. Thus, the activation of the mediating rhyme word would not be strong enough to spread to the semantic network.

In summary, studies of normal subjects provide inconsistent evidence for mediated priming between hypothesized phonological and semantic lexicons. There is some evidence of mediated priming for words that share initial phonological information (Marslen-Wilson & Zwitserlood, 1989), although the conditions of this study are not directly comparable to those using rhyme relationships. The results of rhyme priming studies are equivocal, whether they investigate the spread of priming from semantic to phonological or from phonological to semantic lexicons, and whether they use words or non-words as primes.

The Aphasic Lexicon

The investigation of lexical access in aphasic patients is complicated by a number of factors not relevant to normal populations. With normal populations, the assumption of normality allows inferences to be drawn from lexical access studies that may have an impact upon psycholinguistic models. However, even within normal studies, there occur contradictory findings as a result of subject variables and methodological differences. With aphasic populations, differential deficits are displayed by the various subtypes of aphasia based on site of lesion (e.g. Goodglass & Kaplan, 1983). Impairments at different levels of processing vary in severity and probably interact so that their specific contributions are difficult to assess. In addition, clinical subgroups are hardly homogeneous. Even within diagnostic groups, clinical evidence shows that characteristics are inconsistent across individuals, and these inevitable subject variables must be kept in mind when interpreting results and generalizing them to other patients or situations. Therefore, it is necessary with normals, and even more so with aphasics, to provide converging evidence from a variety of subject samples, using a variety of methods. Only then can results from studies of aphasic patients be incorporated into normal models of lexical processing.

In this section, a number of studies are presented which illustrate the issues foremost in lexical access research with aphasic subjects. How does the performance of aphasic subjects differ from that of non-aphasic subjects? Is semantic processing affected? Is phonological processing affected? Is the coordination of semantic and phonological processing affected? Do impairments reflect clinical subtypes? Do differences in performance from normal subjects reflect disruptions in lexical structure per se, or in access to the lexicon?

Semantic Studies

Early studies of the semantic structure of the lexicon, like those with normals, used paradigms involving conscious semantic processing. Differences in the ability to categorize nouns, using a variety of tasks, have been found between mild and severe aphasics from all diagnostic groups (Lhermitte, Derouesne & Lecours, 1971), and between anterior and posterior aphasics (Zurif, Caramazza, Myerson & Galvin, 1974), high-comprehension and low-comprehension aphasics (Goodglass & Baker, 1976), Broca's and anomic aphasics (Whitehouse, Caramazza & Zurif, 1978), and fluent and nonfluent aphasics (Kudo, 1987).

In general, the above studies suggest that aphasics with anterior lesions perform in a manner similar to normals, although more slowly and less accurately. On the other hand, aphasics with posterior lesions, especially more severely affected patients, often show a disrupted pattern of performance, or no consistent pattern at all. Aphasics with anterior lesions are usually non-fluent (mostly Broca's) aphasics, who tend to be more mildly affected and retain a higher level of comprehension than fluent aphasics, while posterior lesions usually result in fluent (e.g. Wernicke's) aphasia, which tends to be more severe and involve a lower level of comprehension (Goodglass & Kaplan, 1983). ecause of these generalities, aphasics are often grouped into two such broadly dichotomous groups for experimental purposes.

Certain stimulus variables can affect the performance of aphasic groups relative to normal groups. For example, aphasic subjects perform relatively more poorly than non-aphasic subjects in the classification of low-dominance category exemplars than high-dominance exemplars (e.g. Koemeda-Lutz, Cohen & Meier, 1987). This drop in performance has been found to be greater for posterior than anterior aphasic subjects (e.g. Grober, Perecman, Kellar & Brown, 1980; Kudo, 1987). The type of semantic relationship between two words may also differentially affect the performance of aphasic subjects. For example, Goodglass & Baker (1976) found similar patterns of performance for high-comprehension aphasic and non-aphasic subjects across different types of semantic relationship, while low comprehension aphasic subjects showed a different pattern, responding with relatively greater accuracy and speed to contrast coordinates (e.g. ORANGE-APPLE) and with relatively less accuracy and speed to function associates (e.g. ORANGE-EAT).

While the above studies have been interpreted as evidence for the disruption of the semantic lexicon, especially in posterior aphasic patients, another interpretation is possible. It may be that the aphasia has disrupted, not the organization, but the retrieval from the lexicon of certain lexical items. If it is true that it is the retrieval of lexical items that is impaired, and not lexical structure per se, then the type of task used is important. For example, semantic judgement tasks such as those described above involve conscious manipulation of semantic information, while more on-line tasks, such as priming paradigms, tap into automatic processes, and reflect more about actual language processirg.

Milberg & Blumstein (1981) used a semantic priming paradigm to investigate the operation of automatic and conscious processes in Wernicke's and Broca's aphasics. As a measure of automatic lexical access, they used a visual lexical decision task. Word targets in the experiment were preceded by either semantically related words, unrelated words, or nonwords. For normals and Wernicke's aphasics, reaction times to related word pairs were faster than to unrelated word pairs and non-word/word pairs; Broca's aphasics showed no significant differences between related and unrelated word pairs, although word primes taken together resulted in faster reaction times than did non-word primes. Wernicke's aphasics had longer latencies and made more errors overall than Broca's aphasics who, in turn, had longer latencies and made more errors than normals.

As a measure of conscious lexical processing, a semantic judgement task was administered, in which a sub-set of the stimuli was presented orally and visually, and subjects were required to judge whether each word pair was related or not. Correlational analyses on the two types of tasks revealed that the semantic judgement task was not significantly correlated with the priming task, but was significantly correlated with auditory comprehension ability.

The experimenters concluded that, although longer latencies and higher error rates in the lexical decision task suggest that Wernicke's aphasics had some deficit in automatic semantic processing, the presence of semantic priming effects suggests that semantic structure is intact in Wernicke's aphasics. Milberg & Blumstein (1981) proposed that it is the volitional decision stage with which Wernicke's aphasics have difficulty in the lexical decision task, supporting this contention with previous findings that posterior aphasics have greater difficulty than anterior aphasics in semantic judgement tasks (e.g. Grober et al., 1980; Kudo, 1987). They do not report their own semantic judgement findings for the different groups other than to say that the two subjects with the most severely impaired auditory comprehension (a Wernicke's aphasic and a Global aphasic) could not perform the semantic judgement task, but still showed semantic priming effects. It is unclear why Broca's aphasics did not show any significant semantic priming effects. This finding suggested to the researchers that non-fluent aphasics may have a deficit in the automatic access of the semantic lexicon (Milberg & Blumstein, 1981).

In a replication of this study in the auditory modality, Blumstein, Milberg & Shrier (1982) found that reaction times were faster to related than to unrelated words for all subject groups (Wernicke's, Broca's, conduction and global aphasics). No significant differences between groups were found in either the lexical decision or the semantic judgement task, a finding that was attributed to a high level of subject variability. Because of this variability, clinical sub-types were pooled together and grouped instead by level of comprehension. When analyzed in this way, similar priming effects were found across groups in the lexical decision task. On the semantic judgement task, however, high-comprehension aphasics performed better than low-comprehension aphasics. These results are consistent with those reported by Milberg & Blumstein (1981), in that semantic structure, evidenced by semantic priming effects, appears to be preserved even in global aphasia. The ability to access semantic information in order to make metalinguistic judgements, however, may be more impaired in low-comprehension than in high-comprehension aphasics (Blumstein et al., 1982). Error rates in this task, however, were lower than those in the lexical decision task for all groups.

Chenery, Ingram & Murdoch (1990) further investigated differences between automatic and volitional processing by replicating the semantic priming task used by Blumstein et al. (1982) and the semantic judgement task used by Goodglass & Baker (1976) which examined several different types of semantic relationship in a single experiment. Chenery et al. (1990) compared high-comprehension (HC) and low-comprehension (LC) aphasics to two control groups--a neurologically normal group and a non-aphasic brain-damaged group. Consistent with the findings of Goodglass & Baker (1976), results of the judgement task demonstrated that HC aphasics showed a pattern similar to both control groups across types of semantic relatedness, whereas LC aphasics showed a different pattern, responding relatively more quickly and with greater accuracy to contrast coordinates, and less quickly and with less accuracy to functional associates.

In the priming task, however, all groups showed the same pattern, as in the Blumstein et al. (1982) study. Facilitation of semantic relatedness was not significant according to the distribution of reaction times, but significantly fewer errors were made on semantically related targets than on semantically unrelated targets. Despite the weak semantic priming effect, an important finding was that low-comprehension aphasics performed similarly to high-comprehension aphasics and normal subjects on a task requiring on-line semantic processing, but differently from these other groups on a task requiring metalinguistic processing.

Evidence from semantic studies, taking on-line and off-line measures into account, suggests that the structure of the semantic lexicon is largely preserved in aphasia. However, access to lexical items is impaired to some extent in all aphasics, depending on the items used and the processing required in the task. Fluent aphasics appear to have particular difficulty making semantic judgements, a conscious, metalinguistic requirement, while non-fluent aphasics may have reduced automatic access to the lexicon (Milberg & Blumstein, 1981; Blumstein et al., 1982).

Semantic and Phonological Interaction

Research on phonological relationships between words in aphasic patients is scarce. Several studies, however, have addressed the interaction between semantic and phonological information within the lexicon. A dissociation between semantic and phonological information is supported by case studies of anomic patients with profiles showing either semantic or phonological deficits (e.g. Kay & Ellis, 1987; Hadar, Jones & Mate-Kole, 1987). In a study of eight anomic aphasics, Gainotti, Silveri, Villa & Miceli (1986) concluded that there are two types of anomia: semantic anomia, characterized by semantic paraphasias and lexical comprehension disorders, and an expressive anomia, characterized by partial phonological knowledge of unnamed words, the ability to benefit from phonemic cueing, and virtually no lexical comprehension disorder. In the former, the experimenters hypothesized, the semantic lexicon itself is disrupted, giving rise to both expressive and receptive impairments; in the latter, the deficit lies in the connection between the semantic representation and its phonological form.

While production tasks such as picture-naming involve a postulated link from the semantic to the phonological network, perception tasks implicate a link from the phonological to the semantic network. Several studies have explored the phonemic discrimination abilities of aphasic subjects in relation to their auditory comprehension (i.e. semantic processing) deficits. In an auditory same-different judgement task, Blumstein, Baker & Goodglass, 1977 compared four groups of aphasics: Broca's, Mixed Anteriors, Wernicke's, and unclassified Posterior aphasics. Wernicke's aphasics, who as a group had the most severe auditory comprehension deficits, did not achieve the lowest score in phonemic discrimination; the Mixed Anterior grouped made the most errors, the Broca's aphasics made the fewest errors, and the Wernicke's and unclassified Posterior groups fell in between. All groups had more difficulty discriminating non-words than words, suggesting that there was a lexical influence on their discrimination abilities.

In a later study (Baker, Blumstein & Goodglass, 1981), three different phonemic discrimination tasks were used, and only two subject groups were used--Broca's and Wernicke's aphasics. In an auditory word same-different judgement task (requiring only phonological processing) the Wernicke's group made more errors and had longer latencies than the Broca's aphasics, as in the Blumstein et al. (1977) study. In a same-different judgement task using an auditory word and a picture, which required semantic processing in assigning a name to the picture, error rates and latencies increased for both groups, but more so for Wernicke's than Broca's aphasics. The third task, a multiple-choice task, required the subject to choose the picture matching an auditorily presented word from among semantic, phonemic, and unrelated foils. In this task, Wernicke's aphasics made more semantic than phonological confusions, while Broca's aphasics made the same number of each type of error. Wernicke's aphasics consistently performed more poorly than Broca's aphasics, and their performance became worse as semantic demands were introduced (Baker et al., 1981).

Taken together, these two experiments suggest that the auditory comprehension deficit of Wernicke's aphasics may be partially attributable to an impairment in phonemic discrimination, but that semantic processing is also implicated. The experimenters concluded that Wernicke's aphasics have a "tenuous bond" between semantic and phonological representations. Such a conclusion is also supported by the findings of Goodglass, Wingfield, Hyde & Therkauf (1986): while all aphasics showed a frequent inability to name objects that they could nonetheless recognize, only fluent aphasics were sometimes unable to recognize objects that they could name.

Milberg, Blumstein & Dworetzky (1988b) studied the bond between phonological and semantic representations in aphasics more directly by replicating their mediated priming task conducted with normals (Milberg et al., 1988a). Subjects included a variety of clinical sub-types of aphasic patients: Wernicke's, Broca's, Global, Transcortical Sensory, Transcortical Motor, Mixed Transcortical, Conduction, Alexic, Anomic, and Anterior aphasics.

Results showed that, when subjects were divided according to level of auditory comprehension (high vs. low), both groups showed a significant effect of priming condition, with related and mediated conditions faster than unrelated conditions, similar to the effects of normals in the previous study. There was no significant difference between groups, nor was there a significant interaction between group and condition. When subjects were divided into fluent and non-fluent groups, again a significant main effect of priming effect was found but no significant main effect of fluency. The patterns shown by fluent and non-fluent aphasics were different, though, as evidenced by a significant interaction between condition and group. Non-fluent aphasics showed priming only for undistorted primes (i.e. only real-word semantically related pairs), whereas fluent aphasics showed priming for all related primes, distorted and undistorted (i.e. semantically related and mediated pairs) . Milberg et al. (1988b) concluded that non-fluent aphasics appear to have an increased sensitivity to phonological distortion, while fluent aphasics appear to have a decreased sensitivity to phonological distortion. However, it is unclear from these results whether the disruption in mediated priming effects is due to a breakdown within phonological relationships or a breakdown between phonological and semantic representations.

It appears that most aphasic patients have difficulty with tasks involving both semantic and phonological processing, although the results of different studies appear to be contradictory. While some tasks suggest that the link between phonological and semantic information is disrupted in fluent aphasics (e.g. Baker et al., 1981), others suggest that the link is disrupted in non-fluent aphasia (e.g. Milberg et al., 1988b)

Summary

Previous research has provided robust evidence for a semantically organized network in the language processing system of non-brain-damaged individuals. Studies also provide support for a phonologically organized network, but is not clear how such a network would be structured. There is evidence suggesting that rhyme relationships are important, but that word onsets may also play a role, especially in auditory language processing. Evidence of non-word priming suggests that phonological relationships also exist at a sub-lexical level.

The majority of research with aphasic patients suggests that lexical structure remains intact, but that access to lexical items may be impaired (e.g. Milberg & Blumstein, 1981; Chenery et al., 1990). Alternatively, the links between semantic and phonological networks may be disrupted, resulting in word-finding problems in language production and auditory comprehension difficulties in language perception. If phonological links in the lexicon are less well established than semantic links, they may be more susceptible to disruption. Although many differences in ability have been found between clinical sub-types of aphasia, no method of categorizing aphasia has yielded consistent patterns of results across different types of tasks. Broad dichotomous classifications, although less valuable in the clinical setting, seem to be more sensitive in measuring performance differences in experimental testing. The high-comprehension vs low-comprehension classification appears to be more relevant than clinical diagnostic subgroups in semantic priming tasks (e.g.

Blumstein et al., 1982). The fluent vs non-fluent dichotomy provides a clearer pattern of results than either high- vs. low-comprehension or agrammatic vs non-agrammatic in phonological priming (Milberg et al., 1988b).

The Present Study

The purpose of the present experiment is to extend the body of literature on phonological priming to the aphasic population, and to confirm the results of phonological priming with normal subjects, as a basis for further research into mediated priming. Because findings of mediated priming are inconclusive with both normal and aphasic subjects, it is necessary to break down the process of mediated priming into its component processes. If lexical activation does not spread from a phonological representation to a semantic representation (e.g. Burton, in press; Milberg et al., 1988b), which link is missing: the link between phonologically similar representations, the link between semantically related representations, or the link between a word's phonological code and its semantic code?

Studies of semantic priming abound, and provide strong evidence for the spread of activation within a semantic lexicon, at least for normal and fluent aphasic subjects. Studies of phonological priming are less conclusive for normal subjects, and virtually non-existent for aphasic subjects. This study, therefore, focusses on the phonological processes in lexical access. Specifically, the following questions are asked: (1) Can the activation of a word be primed by a rhyming word or non-word? (2) Will the patterns of phonological or rhyme priming differ across groups of fluent aphasic, non-fluent aphasic and normal subjects?

A rhyme priming lexical decision paradigm similar to that of Burton (in press) was used to test normal, non-fluent aphasic, and fluent aphasic subject groups. A rhyme judgement task was also included in order to assess how easily subjects are able to detect and consciously judge rhyme relationships between stimuli. It was predicted that normal subjects would show clear evidence of identity and rhyme priming for both word and non-word primes, and both word and non-word targets, in the lexical decision task, consistent with Burton (in press). In addition, identity priming was expected to be greater than rhyme priming. While non-word priming could only occur at a sub-lexical level, word rhyme priming may be explained either as a result of spreading activation within a phonological lexicon, consistent with Collins & Loftus (1975) and Morton (1969), or as a result of sub-lexical priming, consistent with Forster (1976) and McClelland & Elman (1984). Any findings of rhyme priming in normal subjects may be interpreted as being inconsistent with cohort theory

(Marslen-Wilson & Welsh, 1978), because of its emphasis on word onsets in lexical access.

In the rhyme judgement task, rhyming primes were expected to facilitate rhyme judgements, for both word and non-word primes, with both word and non-word targets. Since rhyme judgements may be made without accessing the lexicon, neither the lexical status of the prime nor the lexical status of the target was expected to influence reaction times. In addition, normal subjects were expected to perform with a high level of accuracy on this task.

Based on Milberg et al.'s (1988b) finding that fluent aphasics showed priming in all mediated rhyming conditions, fluent aphasics were expected to show rhyme priming with both word and non-word rhyme primes in the lexical decision task. In addition, this priming was expected to be as strong for rhyming conditions as for identity conditions, reflecting their hypothesized "over-activation" of lexical items. In Milberg et al.'s (1988b) experiment, non-fluent aphasics did not show any effects of mediated rhyme priming. This finding may be due to a lack of rhyme facilitation for non-fluent aphasics. In that case, non-fluent aphasic subjects would not be expected to exhibit rhyme priming with word or non-word primes. Due to their increased sensitivity to "phonological distortion" (Milberg et al., 1988b) and to the lexical status of the prime (Milberg & Blumstein, 1981), non-fluent aphasics may be even less likely to exhibit rhyme priming with non-word primes than with word primes. Longer latencies and higher error rates than normal subjects were expected for both aphasic groups.

Because the rhyme judgement task does not necessitate lexical access, it was expected to be easier for aphasics to perform. Fluent aphasics, however, were expected to perform more poorly than non-fluent aphasics, because they have been shown to have more difficulty making phonemic discriminations (e.g. Baker et al., 1981; Blumstein et al., 1977) and in making conscious judgements of a metalinguistic nature (Milberg & Blumstein, 1981; Blumstein et al., 1982). As in Blumstein et al. (1977) rhyme judgements were expected to be easier with words than with non-words for both aphasic groups.

METHOD

Subjects

Three groups of subjects participated in the study: ten control subjects, eleven non-fluent aphasic subjects, and nine fluent aphasic subjects. Control subjects were chosen from a pool of adult volunteers for language research at McGill University, and were paid for their participation. All were native speakers of English with no significant hearing impairment and no history of stroke or other brain injury. Their ages ranged from 46 years to 75 years, with a mean of 64 years, 7 months. One of the subjects was male and nine were female.

Aphasic subjects were recruited from the speech-language pathology departments of several hospitals in the Montreal and Ottawa areas. All had suffered a unilateral stroke in the left hemisphere at least four months prior to testing, and all were right-handed. Subjects were classified as fluent or non-fluent based on results of tests conducted by speech pathologists involved in the patients' therapy. The dimension of fluency, as well as having clinical relevance, has been shown to be a salient factor in phonological processing (Milberg et al., 1988b). The mean age of the non-fluent aphasic group was 64 years, 10 months, with ages ranging from 35 to 81 years; the mean age of the fluent aphasic group was 70 years, 5 months with ages ranging from 55 to 80 years. Four of the non-fluent aphasics were male and seven female; of the fluent aphasics, four were male and five female. Subject information is presented in Table 1.

Table 1: Background Subject Information

Control Subjects (CS)

Subject	Age	Sex
CS-1	68	F
CS-2	65	M
CS-3	62	M
CS-4	67	F
CS-5	69	F
CS-6	69	M
CS-7	61	F
CS-8	67	F
CS-9	75	F
CS-10	63	F
CS-11	46	F
CS-12	63	F
Mean	65	

Non-Fluent Aphasic Subjects (NFAS)

Subject	Age	Sex	Months Post-Onset	Lesion Site
NFAS-1	35	F	40	L frontal hypodensity
NFAS-2	41	M	28	L frontoparietal hypodensity
NFAS-3	73	M	5	N/A
NFAS-4	70	F	7	L frontal
NFAS-5	57	F	24	L MCA distribution
NFAS-6	64	F	35	N/A
NFAS-7	76	M	59	N/A
NFAS-8	80	F	8	L MCA distribution
NFAS-9	81	F	37	L MCA distribution
NFAS-10	66	M	41	L frontal
NFAS-11	72	F	19	N/A
Mean	65		28	

Fluent Aphasic Subjects (FAS)

Subject	Age	Sex	Months Post-Onset	Lesion Site
FAS-1	79	M	11	N/A
FAS-2	67	F	21	L frontoparietal
FAS-3	70	M	23	L MCA distribution
FAS-4	69	F	23	N/A
FAS-5	73	F	18	L frontoparietal
FAS-6	55	F	20	L MCA distribution
FAS-7	67	M	5	L MCA distribution
FAS-8	74	F	4	L temporal
FAS-9	80	M	33	N/A
Mean	70		18	

Stimuli

Stimuli consisted of pairs of monosyllabic CVC English words and pseudowords. The first string in each pair was considered the prime; the second string was considered the target. Five different prime-target relationships were constructed: 1) an identity relationship (ID), in which the prime and target were the same (e.g. BOOK-BOOK), 2) a rhyming word relationship (WR), in which the prime was a word that rhymed with the target (e.g. LOOK-BOOK), 3) a non-word rhyming relationship (NWR), in which the prime was a pseudoword that rhymed with the target (e.g. ZOOK-BOOK), 4) a non-rhyming word relationship (WNR), in which the prime was a word which was phonologically unrelated to the target (e.g. RAISE-BOOK), and 5) a non-rhyming non-word relationship (NWNR), in which the prime was a pseudoword which was phonologically unrelated to the target (e.g. LEETHE-BOOK).

The phonologically unrelated primes were included as baselines against which to measure the rhyming primes to determine whether the rhyming relationship would have an effect on subjects' responses. Identity primes were included in the experiment in order to replicate Burton's (in press) rhyme priming experiments, and to serve as another form of baseline for the rhyming word primes. Non-rhyming word primes were phonologically unrelated in any way to their targets, whereas identity primes were maximally phonologically related to their targets.

The stimulus pairs were derived from the set of monosyllabic CVC English words with a frequency of occurrence greater than 50 per million (Francis & Kucera, 1982). Only uninflected content (open-class) words--nouns, verbs, and adjectives--were included, and words with homophones or unusual spellings were excluded to minimize orthographic confounds. These words were arranged into twenty rhyming pairs, of which the VC portions (rimes) were spelled the same. One of these was designated the target, the other its WR prime. A third, non-rhyming word from the original set of high-frequency words was grouped with each pair, as the target's WNR prime. Each target was also used as an "identity" prime for itself. None of the words within a set were semantically, associatively, or syntactically related, and none shared initial phonemes.

The initial phoneme of each target was altered to create a non-word rhyming (NWR) prime for each set. A non-rhyming non-word (NWNR) prime was also created for each set by altering the initial phonemes of unused CVC words from the original set of high frequency English words. An additional non-rhyming non-word was similarly created for each set as a "filler" (FIL condition) to equalize the number of word and non-word primes. All non-words were constructed according to the phonotactic constraints of English. In addition, an effort was made to create non-words with initial phonemes in approximately the same proportions as they occurred in the real words (so that not all non-words would begin with "z" and "y", for example). No VC ending was used in more than one set, so that none of the CVC strings in one set rhymed with a CVC string in a different set.

Twenty more stimulus sets were constructed with non-word targets instead of word targets. Each non-word target was paired with the same six prime conditions as were the word targets except that, for non-word targets, words were used as filler (FIL) primes in order to equate the number of word and non-word primes. Again, real-word primes were chosen from the original set of high-frequency English CVC content words.

Thus, there were twenty word targets and twenty non-word targets, so that equal numbers of "yes" and "no" responses were required. For each target there were three word and three non-word primes; three of these were rhyming primes and three were non-rhyming primes. (The identity prime was considered to rhyme with the target.) In all, 240 stimulus pairs were presented. A complete list of the test stimuli is presented in Appendix A.

Finally, ten extra prime/target pairs were constructed to serve as pre-test practice trials for each subject. These included word and non-word targets preceded by WR, NWR, WNR, and NWNR primes. None of the practice items appeared among the test stimuli.

Stimulus words were recorded individually by a male native English speaker in a sound-attenuated booth using a portable cassette recorder (Sony Professional Walkman WM-D6C) and a unidirectional microphone (Sony ECM-909); the stimuli were then digitized at a sampling rate of 10 kHz, with a 4.5 kHz low-pass filter and 12-bit quantization. Using the BLISS speech analysis system (Mertus, 1988), prime/target pairs were matched for presentation to subjects with a 500 msec inter-stimulus interval, and a 6 sec inter-trial interval to ensure adequate time for response.

Word and non-word targets were randomly ordered six times, once for each time they were to be presented, to ensure maximal distance between repeated target presentations. The repetition of targets was not of major concern because Burton (in press) found that the results of her auditory lexical decision experiment with normal subjects were not influenced by varying the use of repeated or non-repeated targets. Furthermore, it is preferable to present all stimuli to each aphasic patient, due to the high individual variability in this subject population. The primes for all targets were then pseudo-randomly ordered to ensure that all possible orders of primes were represented in equal numbers. The stimulus set was then recorded onto a cassette tape for presentation to subjects for the lexical decision and rhyme judgement tasks. A second tape was made for a lexical decision of primes task, consisting of the 200 primes (omitting ID primes) presented singly in random order, with an inter-trial interval of 4 sec.

Procedure

The taped stimuli were presented on the portable Sony tape player through an amplifier (Heathkit Solid State) to which two sets of headphones (Sony MDR-V1) were connected. The subject and the experimenter both listened through the headphones to the left channel of the tape (containing the prime-target pairs) which was presented binaurally. A tone on the right channel of the tape (recorded 20 msec prior to the onset of the target word) activated a voice-operated relay (Lafayette 6602A) connected to a millisecond counter (Lafayette 54035). The counter was stopped when the subject pressed one of two buttons labelled "yes" and "no" on a response board.

The experiment consisted of three separate tasks: an auditory lexical decision task (LD), an auditory lexical decision of primes post-test, and an auditory rhyme judgement task (RJ). In the first lexical decision task, subjects were required to judge whether or not the second word, or target, in each of the 240 stimulus pairs was a real word. Instructions were given as follows:

> You will hear pairs of words over the headphones. Some will be real words, some will be made-up, or nonsense words. Don't answer to the first word in each pair, just answer to the second word in each pair. If the second word is a real word, answer "yes" (demonstrated by pushing "yes" button); if it is a made-up word, answer "no" (demonstrated "no" button). The real words are all common one-syllable words; no proper names, no slang words. The object is to answer as quickly as possible, but without making mistakes. Use the hand you feel most comfortable using, but use the same hand for both buttons. Before starting the test, we'll do ten pairs of practice words, then we'll stop the tape. Remember, only answer to the second word in each pair. Yes, it's a real word or no, it's not a real word. Ready?

Practice trials were presented first, then the tape was stopped to verify that the volume was adequate and that the task was understood. Some of the aphasic subjects who showed confusion or who performed poorly on the practice trials needed extra training with orally presented pairs.

The lexical decision task was presented next. After the LD task, a post-test was given in which the 200 randomly ordered primes was presented and subjects were required to judge the lexical status of each one. Subjects were told that this test was similar to the one they had just completed, except that the words would come one at a time, and they were to answer to every word. This post-test was included in order to verify that the primes were being heard correctly as words or non-words. It was presented after the LD task and before the RJ task, because the similarity of response requirements of the LD task and the post-test would reduce potential confusion. In addition, in this order the time between the two experimental tasks (LD and RJ) which used the same set of stimuli was maximized.

In the rhyme judgement task, the 240 taped stimuli were again presented, but this time subjects were instructed to judge whether or not each pair rhymed, regardless of the lexical status of its members. No practice trials were required for the normal subjects, but examples of rhyming and non-rhyming pairs were presented to some of the aphasic subjects before beginning the RJ test.

The reaction time of each correct response was recorded. No feedback was given to subjects regarding the accuracy or speed of their responses. The order of the tests and the order of stimuli within each test was the same for all subjects. Subjects were tested individually in a single session, except for one non-fluent aphasic subject who tired easily and was therefore administered the three tests on three successive days. Each test took about one-half hour to complete; the entire procedure lasted approximately one and one-half hours.

RESULTS

Control Subjects (CS)

A control group was tested in order to replicate the results of Burton (in press). Their performance also served as a baseline against which to measure the performance of the aphasic subjects. Because high error rates within the control group would reduce the amount of data to be analyzed, and therefore the reliability of the results for the normal group, a criterion was set for each control subject of at least 75% response accuracy on both word targets and non-word targets in each task (cf. Burton, 1988). Appendix B displays the percentage of errors made by each subject in each condition and the overall percentages of errors made by the control subjects as a group on word targets and non-word targets in both tasks. The error rates of two subjects (CS-3 and CS-6) exceeded 25% for non-word targets in the lexical decision task. Therefore the data of these two subjects were excluded from all further analyses of both lexical decision and rhyme judgement tasks, leaving ten subjects in the control group.

High error rates on particular stimulus items would similarly reduce the reliability of the results. Therefore, individual items were analyzed across the remaining ten control subjects to determine whether any of the targets or any of the primes were frequently misperceived. (Only lexical decision responses were analyzed, since the object was to eliminate any confusion over the lexical status of primes and targets.) A criterion of 75% accuracy was set for targets, and 50% accuracy for primes. A lower rate of accuracy was accepted for the primes since they were heard only once in each test, while targets were heard seven times per test, including their presentation as identity primes.

Error rates for each target in the lexical decision (LD) task were calculated and are presented in Appendix C. One non-word target (KIDE) had an error rate of 38.0% across subjects, and was therefore eliminated in all of its conditions. None of the word targets exceeded the criterion of 75% accuracy. Error rates for each prime in the lexical decision post-test were calculated for the control group and are presented in Appendix D. The error rates of three non-word primes exceeded 50% across subjects: ROG-90%, KATH-70%, and SATHE-90%. Therefore, the targets for these three primes (CHUN, FULL, and LOCK, respectively) were eliminated in all of their conditions. None of the word primes exceeded the criterion of 50% accuracy. In all, two of the twenty non-word target sets (CHUN and ROG) and two of the twenty word target sets (FULL and LOCK) were eliminated from all further analyses of the LD task for control and aphasic groups.

In each task, reaction times (RTs) were recorded for correct responses only. Twenty msec was subtracted from every RT to compensate for the 20 msec between the tone (which activated the timer) and the onset of the following target. For each subject, mean reaction times and standard deviations (STD) were calculated for each condition. To ensure that response times reflected on-line processes (cf. Katz, 1987, p. 749), all outliers, i.e. RT scores more than two standard deviations above their respective means, were eliminated, and the means were recalculated for each condition. Data from the FIL condition was not included in any statistical analyses, as it was intended only to balance the numbers of word and non-word, rhyme and non-rhyme conditions. Separate analyses were carried out for word and non-word targets, for each task and for each group.

CS: Lexical Decision Task - Word Targets

The overall error rate for word targets in the lexical decision task was 3.0%, once the two control subjects and the four target sets with high error rates were eliminated. The bottom line of Table 2 shows the error rates for each condition. Among the word conditions, identical (ID) primes resulted in fewer errors than rhyming (WR) primes which, in turn, resulted in fewer errors than non-rhyming (WNR) primes. Among the non-word conditions, non-rhyming (NWNR) primes resulted in fewer errors than rhyming (NWR) primes. No statistical analyses were undertaken due to the low rates of errors.

Table 2: CS - Reaction Times (msec) and Error Rates (%) for Word Targets in the Lexical Decision Task

	ID	WR	NWR	WNR	NWNR
CS-1	888	979	986	1092	1065
CS-2	944	1082	1186	1247	1297
CS-4	807	796	766	968	888
CS-5	836	765	877	861	740
CS-7	821	869	918	1009	958
CS-8	824	873	955	994	940
CS-9	1183	905	847	1106	993
CS-10	856	953	835	1003	982
CS-11	702	678	718	881	818
CS-12	807	893	871	996	896
MEAN	877	878	886	1025	968
STD	120	107	122	109	142
ERRORS	1.7%	2.8%	5.0%	3.9%	1.7%

Reaction time data were analyzed across subjects and across items for word targets. Mean reaction times for each condition are presented for each subject, and for all control subjects as a group, in Table 2. Overall, and for all subjects except CS-5 and CS-9, RTs to each of the three rhyming prime conditions (ID, WR, NWR) were shorter than to both of the non-rhyming prime conditions (WNR, NWNR), suggesting a facilitation effect of phonological relationship. Among the rhyming conditions, the mean RTs to targets preceded by ID or WR primes were shorter than the mean RT to targets preceded by NWR primes. Among the non-rhyming conditions, NWNR primes resulted in shorter reaction times than WNR primes. This pattern is similar to the pattern of error rates, indicating there is not a speed/accuracy trade-off.

Item data for word targets in the lexical decision task are presented in Table 3. The pattern of overall means illustrates that the item data closely mirror the subject data.

Table 3: CS - Reaction Times (msec) by Item for Word Targets in the Lexical Decision Task

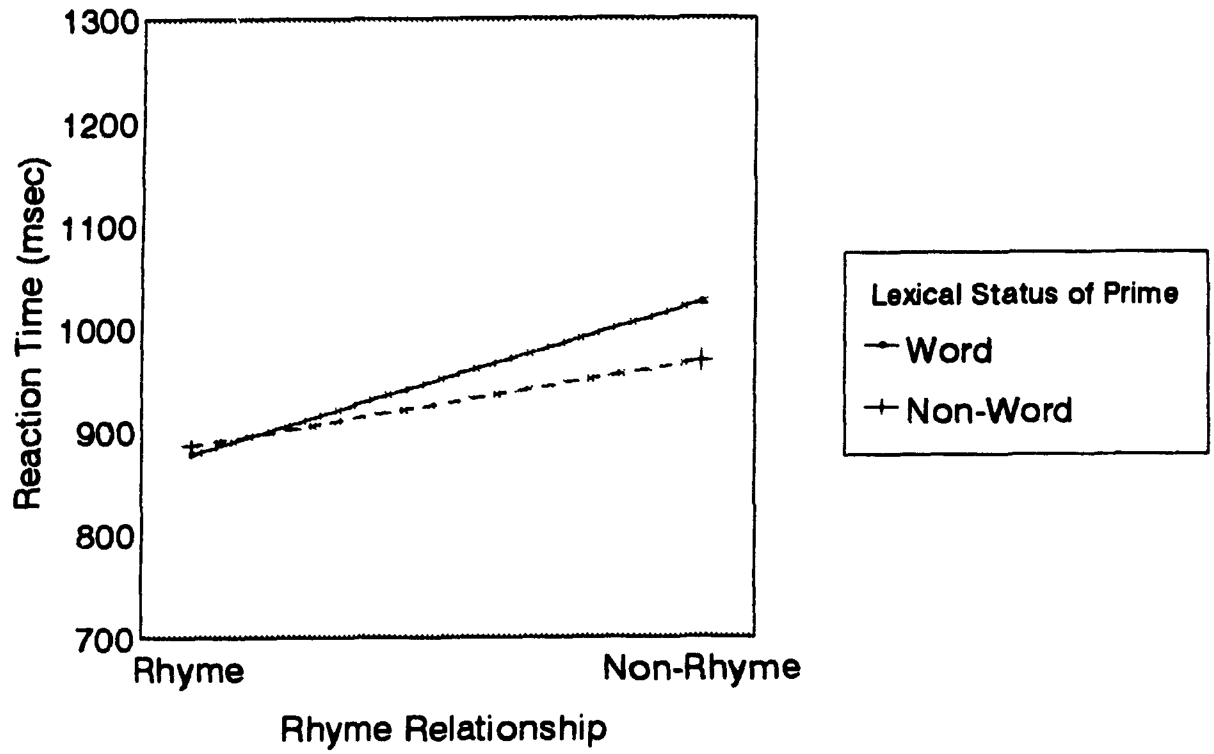
TARGET	ID	WR	NWR	WNR	NWNR
BOOK	790	743	726	693	788
VOICE	902	880	1011	1152	926
GET	905	906	1134	1123	1118
SIT	1020	1003	985	1086	1025
NIGHT	930	873	820	956	991
SHOP	1013	996	909	1208	1164
WILL	814	829	821	912	889
COOL	870	787	784	840	776
WIN	845	830	848	1007	957
BOAT	1113	1017	910	1092	896
RACE	776	940	913	1121	1006
TEACH	710	722	777	1104	964
CUT	642	788	783	779	875
NECK	861	869	888	1192	1080
MEAN	764	724	955	1018	995
SHAKE	926	1097	1078	1146	1041
SAVE	1013	892	9[illegible]7	1065	1077
WRONG	831	1018	875	1054	963
MEAN	874	884	897	1030	974
STD	116	108	105	140	102

Subject and item reaction time data were examined more closely using statistical procedures. Unless otherwise specified, all results are reported at a level of significance of $p < 0.05$. Repeated measures one-way analyses of variance (ANOVAs) were conducted to assess the effect of the degree of phonological relationship between primes and targets. Thus, the three word prime conditions--ID, WR, and WNR--were included. A significant effect of phonological relationship was found using both subject means [$F(2,18) = 16.094$] and item means [$F(2,34) = 19.56$].

Post-hoc Neuman-Keuls tests explored the differences between each pair of means. The mean reaction time to the identity (ID) condition was not significantly different from the mean reaction time to the rhyming word (WR) prime condition, using either subject or item means. However, the ID condition was significantly faster than the non-rhyming word condition (WNR) with subject data and with item data. In addition, the WR condition was significantly faster than the WNR condition. Thus, targets rhyming with their word primes were facilitated relative to targets not rhyming with their word primes.

The effects of lexical status of prime and rhyming relationship using subject data (excluding the ID condition) are presented in Figure 1. (Item data are not presented, since they replicate the subject data.) The figure shows that rhyming targets were responded to more quickly than non-rhyming targets, whether the primes were words or non-words. An interaction between the two variables is also suggested, such that the difference in RT between rhyming and non-rhyming prime/target pairs was greater for word primes (WR vs WNR) than for non-word primes (NWR vs NWNR).

Figure 1: CS - Rhyme and Lexical Status of Prime Effects for Word Targets in the Lexical Decision Task



Two-way (lexical status of prime X rhyme) ANOVAs confirmed a significant main effect of rhyme with subject means [$F(1,9) = 43.046$] and item means [$F(1,17) = 31.277$], but no significant effect of lexical status. The interaction between lexical status of prime and rhyme was significant with both subject means [$F(1,9) = 8.72$] and item means [$F(1,17) = 5.27$].

Post-hoc Neuman-Keuls tests reflected the facilitory effect of rhyme for both word and non-word primes; rhyming word/word pairs were significantly faster than non-rhyming word/word pairs (WR vs WNR), and rhyming non-word/word pairs were significantly faster than non-rhyming non-word/word pairs (NWR vs NWNR), using both subject and item data. Neuman-Keuls tests also revealed that the lexical status of the prime had an effect on non-rhyming prime-target pairs; RTs to targets with non-word primes (NWNR) were significantly longer than to targets with word primes (WNR), using subject means and item means. However, no significant effect of lexical status was found between the rhyming pairs (WR vs NWR). WR pairs, in which the prime and target are related along the dimensions of phonological relationship and lexical status, resulted in significantly faster RTs than did NWNR pairs, which are related along neither dimension. Given the significant rhyming effect and the non-significant lexical effect of the ANOVA, it would be expected that NWR primes (related phonologically only) would result in significantly faster RTs than WNR primes (related lexically only). This was, in fact, the case with both subject and item data. Thus the rhyming relationship proves to be more facilitory than the lexical status of the prime.

CS: Lexical Decision Task - Non-Word Targets

The overall error rate for non-word targets in the lexical decision task was 6.4% for the group of ten control subjects. The last line of Table 4 shows the error rates in each condition.

Table 4: CS - Reaction Times (msec) and Error Rates (%) for Non-Word Targets in the Lexical Decision Task

	ID	WR	NWR	WNR	NWNR
CS-1	1137	1455	1446	1442	1547
CS-2	1295	1370	1427	1419	1487
CS-4	796	971	1027	1007	1117
CS-5	920	1204	1245	1159	1076
CS-7	744	1001	1050	922	1010
CS-8	1024	1236	1201	1224	1275
CS-9	1408	1217	1407	1011	1366
CS-10	934	1018	1132	944	1224
CS-11	940	953	1027	906	1022
CS-12	886	966	1019	952	1040
MEAN	1013	1139	1198	1099	1216
STD	205	173	166	192	187
ERRORS	7.8%	3.3%	6.7%	5.6%	8.9%

Table 5: CS - Item Reaction Times (msec) for Non-Word Targets in the Lexical Decision Task

TARGET	ID	WR	NWR	WNR	NWNR
CHOT	1193	1249	1278	1222	1356
RALL	1291	1125	1412	1146	1325
SHATE	853	1534	1399	1258	1265
NING	945	989	1152	941	1172
DOAN	1104	1222	1453	1197	1463
FIV	944	1016	1403	1187	1078
BAME	1046	1172	1207	1012	1353
FIP	1173	1195	1030	1268	1133
JEAL	1123	1426	1114	1021	1344
ZICK	935	1027	991	882	1059
NASS	868	1052	1198	1150	1087
KILE	990	1112	1443	969	1319
SAR	883	1157	1149	1189	1205
DAGE	867	935	1000	1070	1184
PUTCH	977	1062	1061	1104	1440
KEAT	990	1072	1347	1041	1130
ZACK	853	1271	936	1004	1174
HIFE	1152	959	1088	1152	1092
MEAN	1010	1143	1203	1101	1232
STD	130	155	167	110	125

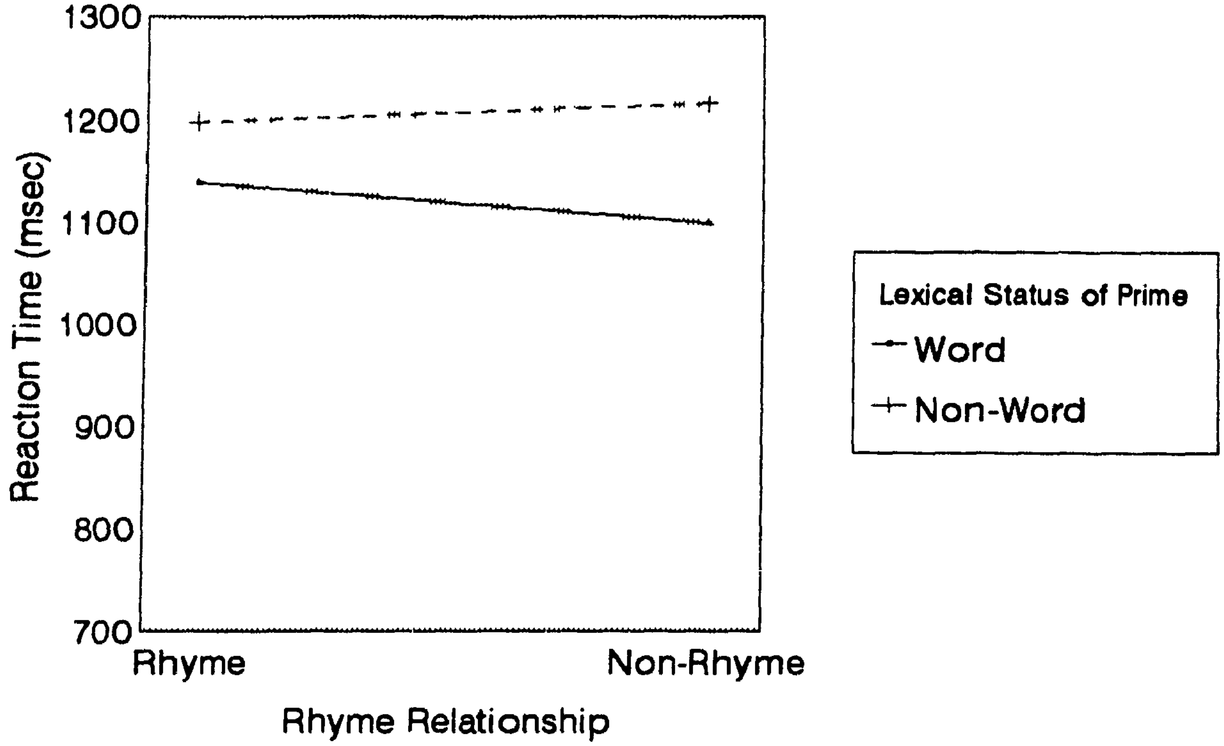
Word primes (WR and WNR) resulted in lower error rates than did non-word primes (NWR and NWNR), and ID primes unexpectedly resulted in the second-highest error rate.

Mean reaction times were calculated for each condition for each subject (listed in Table 4) and each item (listed in Table 5). Group means across subjects showed that, as with word targets, the ID condition resulted in the fastest mean response time. With the exception of subjects CS-9 and CS-11, individual subject means revealed the same pattern. Among the other conditions, word primes resulted in faster RTs than non-word primes for overall group means and for most of the individual subject means. Means for rhyming conditions were not consistently faster than those for non-rhyming conditions. Item means showed the same pattern.

Repeated measures one-way ANOVAs performed on the subject and item means of conditions ID, NWR, and NWNR revealed a significant effect of phonological relationship: [$F(2,18) = 23.706$] for subjects, [$F(2,34) = 17.59$] for items. Post-hoc Neuman-Keuls tests indicated that ID primes resulted in significantly faster RTs than either NWR primes or NWNR primes, for both subject and item data. However, there was, unexpectedly, no significant difference between NWR and NWNR conditions. Thus, only identity facilitated lexical decisions for non-word targets, not rhyming.

Figure 2 displays the effects of rhyme relationship and lexical status of prime for the non-word targets. A lexical

Figure 2: CS - Rhyme and Lexical Status of Prime Effects for Non-Word Targets in the Lexical Decision Task



status of prime effect is suggested by the figure, and an interaction between the two variables. The rhyme effect appears to be negligible. As in the analysis of word target data, two-way ANOVAs were conducted, using subject and item data, to explore the effects of the prime-target rhyming relationship and the lexical status of the prime. The ID condition was again excluded. As suggested by the figure, there was a significant main effect of lexical status of prime in both subject [$F(1,9) = 10.53$] and item [$F(1,17) = 10.15$] analyses, but no significant main effect of rhyme emerged either with subject or item data. There was a marginally significant interaction between rhyme and lexical status of prime in the subject analysis [$F(1,9) =$

4.84, p = 0.055], but the interaction was not significant in the item analysis.

Post-hoc tests were not conducted on the item data, since the item analysis did not find a significant interaction. However, Neuman-Keuls tests were conducted on the subject data to explore the marginal interaction between rhyme relationship and lexical status of prime. No significant differences were found between rhyming and non-rhyming conditions, with either word (WR vs WNR) or non-word (NWR vs NWNR) primes. However, word primes resulted in significantly faster RTs than non-word primes, with both rhyming (WR vs WNR) and non-rhyming (WNR vs NWNR) pairs. As with word targets, WR pairs were significantly faster than NWNR pairs. However, unlike the results for word targets, WNR pairs were responded to faster than NWR pairs, suggesting that for non-word targets, the word status of the prime provided more facilitation than the rhyme status.

CS: Lexical Decision Task - Summary

Both word and non-word targets showed a significant effect of phonological relationship between primes and targets of the same lexical relationship. For word targets, the effect resulted from a significant difference between rhyming and non-rhyming pairs; for non-word targets, the effect resulted from a significant difference between identical and non-identical pairs. These findings suggest that rhyming primes were highly facilitory for lexical decisions with word targets, as facilitory as identical primes, but that the rhyming relationship was not strong enough to facilitate lexical decisions to non-word targets. With non-word targets, only a maximal phonological relationship (i.e. identity) facilitated lexical decisions. As expected, error rates were lower and reaction times shorter overall for word targets than for non-word targets.

CS: Rhyme Judgement Task - Word Targets

The subjects with high error rates excluded from the lexical decision task were also excluded from the rhyme judgement task. Therefore, the control group remains constant with ten subjects. However, the items excluded from the lexical decision task with high error rates were included in this task (RJ), since the misperception of those items as words or non-words may have been a function of the task demands per se and is less relevant in the present task. As with the lexical decision task, word and non-word targets were analyzed separately.

Control subjects had an overall rhyme judgement error rate of 2.6% on word targets. Error rates for each condition are listed at the bottom of Table 6. As in the lexical decision task, the lowest error rates for word targets occurred in the maximally related (ID) and the maximally unrelated (NWNR) conditions.

Table 6: CS - Reaction Times (msec) and Error Rates (%) for Word Targets in the Rhyme Judgement Task

	ID	WR	NWR	WNR	NWNR
CS-1	913	1001	989	1013	939
CS-2	989	1028	1126	1227	1451
CS-4	731	702	737	753	[illegible]
CS-5	655	758	705	1024	839
CS-7	675	853	781	944	777
CS-8	670	730	702	914	954
CS-9	921	822	1037	799	756
CS-10	797	765	776	956	887
CS-11	518	548	617	756	686
CS-12	741	695	739	748	748
MEAN	761	790	821	904	830
STD	138	137	160	148	204
ERRORS	1.5%	5.0%	2.0%	3.0%	1.5%

Mean reaction times for each condition are also listed in Table 6. The pattern of the overall means for word targets in the rhyme judgement task is the same as the pattern for word targets in the lexical decision task: the three rhyming conditions had shorter reaction times than the two non-rhyming conditions. All subjects except CS-1, CS-7, and CS-9 showed the same pattern. The item means (provided in Table 7) also demonstrated this pattern. Subject means and item means were used to perform repeated measures one-way ANOVAs to explore the effect of degree of phonological relationship between word/word pairs. The ANOVAs revealed a significant effect of phonological relationship for subjects [$F(2,18) = 8.86$] and for items [$F(2,38) = 22.33$]. Post-hoc Neuman-Keuls tests indicated no significant difference between ID and WR primes, using either subject or item data.

Table 7: CS - Item Reaction Times (msec) for Word Targets in the Rhyme Judgement Task

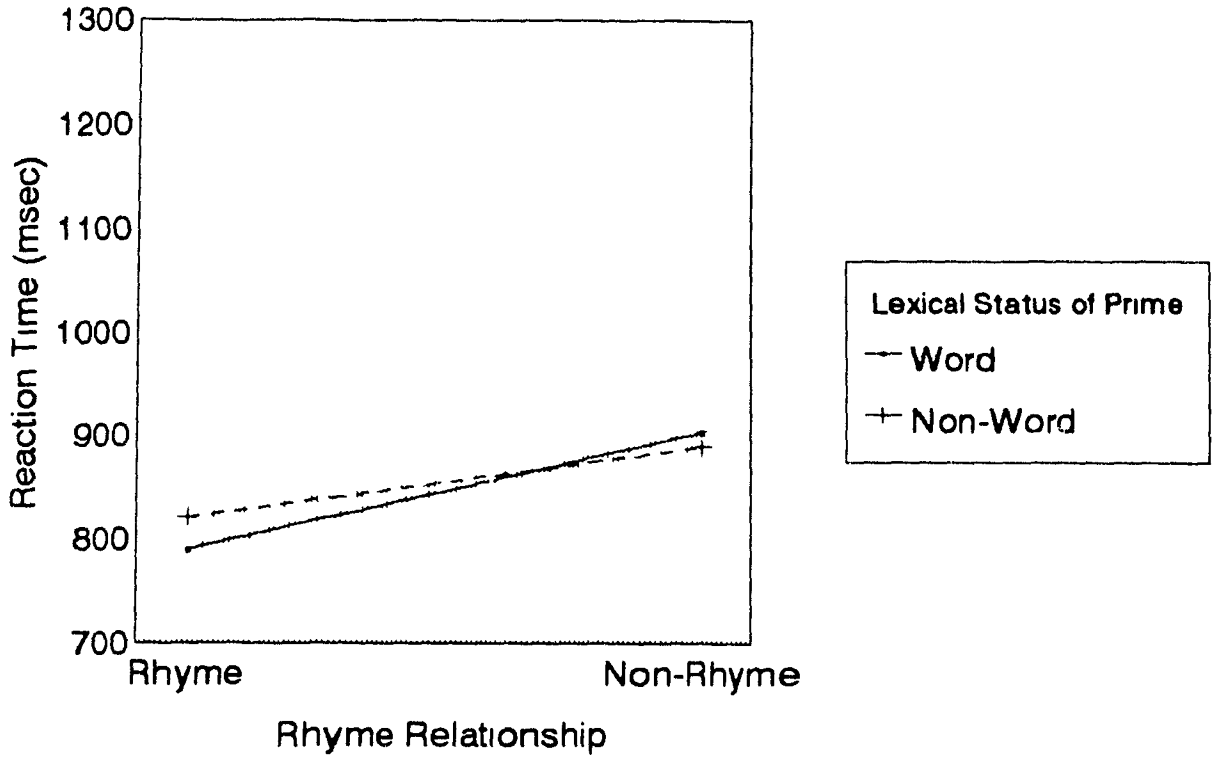
TARGET	ID	WR	NWR	WNR	NWNR
FOUR	635	616	696	784	829
FULL	834	709	928	1096	1040
VOICE	967	778	706	990	1004
GET	711	857	758	793	858
IT	624	840	938	909	957
NIGHT	745	776	863	382	833
SHOP	948	872	1035	1170	924
WILL	793	791	763	897	952
COOL	684	744	763	894	818
WIN	742	736	396	371	730
BOAT	840	789	794	935	594
RACE	747	778	770	885	762
LUCK	940	1059	908	830	835
TEACH	568	610	779	788	930
CUT	717	733	742	304	892
NECK	723	796	678	796	1067
MEAN	648	627	802	773	829
SHARE	688	841	848	934	844
SAVE	852	892	894	926	975
WRONG	679	973	866	1086	923
MEAN	760	790	826	907	893
STD	91	101	87	106	83

However, the ID condition and the WR condition were both significantly faster than the phonologically unrelated (non-rhyming) condition WNR, with both subject and item data.

Figure 3 illustrates the effects of rhyme and lexical status of prime with word targets, using subject data, but excluding the ID condition. Rhyming primes were responded to faster than non-rhyming pairs, especially with word primes.

Two-way analyses of variance comparing the factors of rhyme relationship and lexical status of prime showed a marginally significant main effect of rhyme [$F(1,9) = 5.08$, $p = 0.051$] for subjects, which was, however, more robust

Figure 3: CS - Rhyme and Lexical Status of Prime Effects for Word Targets in the Rhyme Judgement Task



with item data [F(1,19) = 23.47]. Neither the main effect of lexical status of prime nor the interaction were significant using either subject means or item means. Because the interaction was not significant, no post-hoc tests were conducted.

CS: Rhyme Judgement Task - Non-Word Targets

For non-word targets in the rhyme judgement task, the overall error rate was 1.8%. Like the RJ pattern for word targets, the ID and NWNR conditions had the lowest error rates. The error rate for the NWR prime condition was equally low. Table 8 lists the group error rates for each condition.

Table 8: CS - Reaction Times (msec) and Error Rates (%) for Non-Word Targets in the Rhyme Judgement Task

	ID	WR	NWR	WNR	NWNR
CS-1	919	1095	1060	975	1009
CS-2	1133	1189	1148	1343	1360
CS-4	713	819	795	752	781
CS-5	805	872	953	913	873
CS-7	664	943	932	803	841
CS-8	706	767	697	810	838
CS-9	797	960	1029	753	786
CS-10	795	914	976	981	955
CS-11	562	688	601	681	681
CS-12	780	807	773	703	713
MEAN	788	905	896	881	894
STD	147	143	165	186	185
ERRORS	1.0%	3.5%	1.0%	2.5%	1.0%

Mean subject RTs are listed for each condition in Table 8; item RTs are listed in Table 9. The lowest overall mean RT occurred in the ID condition for both subject and item analyses, as expected, but the other two rhyming conditions were unexpectedly slightly slower than the two non-rhyming conditions.

Repeated measures one-way ANOVAs were carried out on the reaction time data of non-word prime conditions. A significant effect of degree of phonological relationship was found with both subject data [$F(2,18) = 5.71$] and item data [$F(2,38) = 15.05$]. Neuman-Keuls tests indicated that the ID condition resulted in significantly faster RTs than both NWR and NWNR conditions with both subject and item data, but that rhyming and non-rhyming non-word primes were not significantly different from each other.

Table 9: CS - Item Reaction Times (msec) for Non-Word Targets in the Rhyme Judgement Task

TARGET	ID	WR	NWR	WNR	NWNR
[illegible]	781	1064	890	889	[illegible]
[illegible] DE	[illegible]	303	[illegible]	[illegible]	948
[illegible]	[illegible]	395	[illegible]	[illegible]	[illegible]
SHATE	[illegible]	480	1048	951	1020
NING	779	[illegible]	[illegible]	926	[illegible]
DOAN	910	880	850	903	939
FIV	868	869	[illegible]	994	948
BAME	907	915	840	[illegible]	944
FIP	953	1061	916	981	[illegible]
[illegible]EAL	694	[illegible]	880	794	839
ZI[illegible]	842	[illegible]	889	850	961
NASS	847	[illegible]	1086	837	[illegible]
[illegible]	[illegible]	[illegible]	915	[illegible]	[illegible]
SAR	757	[illegible]	866	913	[illegible]
CHUN	794	[illegible]	866	920	[illegible]
DAGE	831	762	766	761	966
PUTCH	[illegible]	832	[illegible]	946	[illegible]
[illegible]EAT	655	815	811	903	[illegible]
ZACK	719	[illegible]	[illegible]	807	[illegible]
HIFE	743	880	867	[illegible]	795
MEAN	787	[illegible]	[illegible]	883	[illegible]
STD	63	[illegible]	[illegible]	56	[illegible]

Figure 4: CS - Rhyme and Lexical Status of Prime Effects for Non-Word Targets in the Rhyme Judgement Task

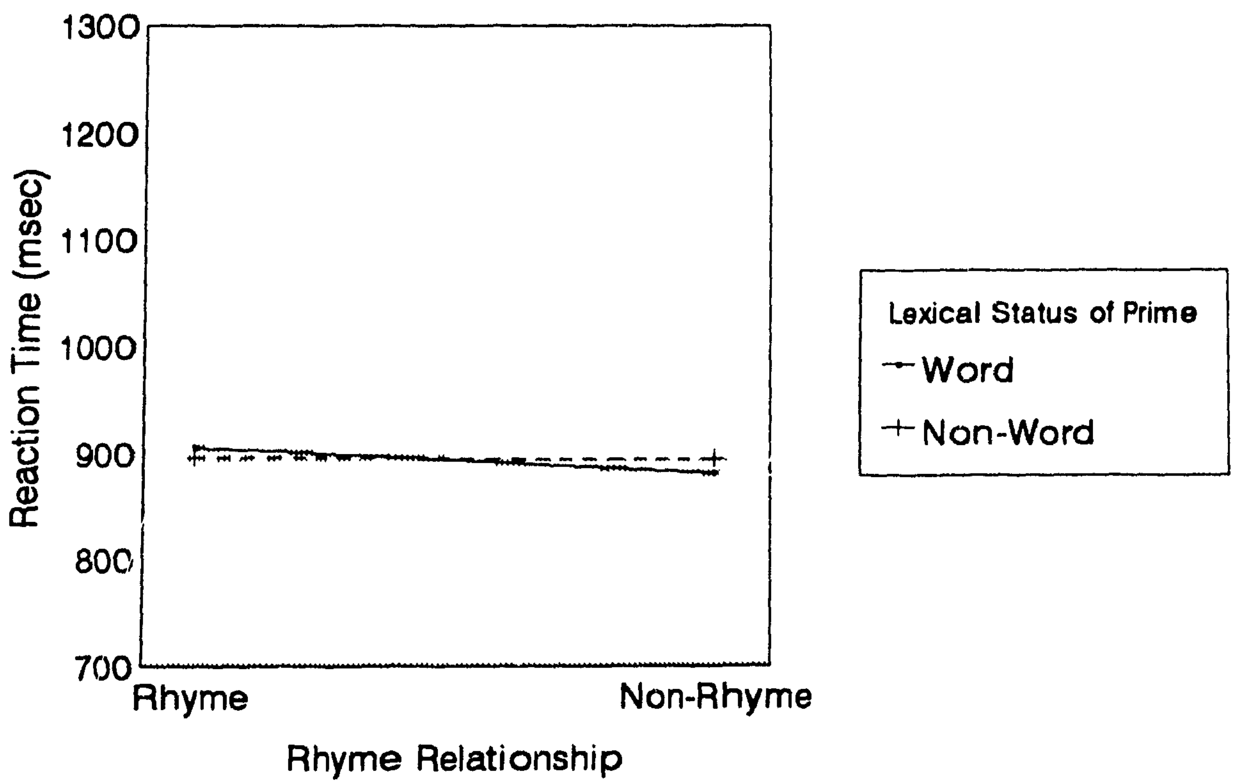


Figure 4 shows the relationship between the two variables, rhyme relationship and lexical status of prime, for non-word targets in the rhyme judgement task. Although the differences in RT between rhyming and non-rhyming conditions are in opposite directions for word and non-word primes, the differences appear to be quite small. Indeed, two-way ANOVAs (rhyme relationship x lexical status of prime) found no significant main effects, nor any significant interaction, with either subject or item data.

CS: Rhyme Judgement - Summary

A significant effect of phonological relationship was found forboth word and non-word targets when the lexical status of the prime and target were the same. As in the lexical decision task, this was due mostly to a significant difference between rhyming and non-rhyming pairs (ID and WR vs WNR) for word targets, but to a significant difference between identical and non-identical (ID vs NWR and NWNR) pairs for non-word targets. Thus, a greater degree of phonological similarity (in fact, maximal) seems to be required to facilitate lexical decisions and rhyme judgements to non-word targets than to word targets.

As with the lexical decision task, a significant main effect of rhyme was found for word targets, but not for non-word targets. That is, "yes" rhyme judgements were made faster than "no" rhyme judgements only when the target was a word. Unlike lexical decisions, however, the lexical status of the prime did not appear to influence rhyme judgements.

Reaction times, as in the lexical decision task, were shorter for word targets than for non-word targets, but the differences were minimal. Error rates were actually lower for non-word targets than for word targets, but, again, only marginally. In general, error rates and reaction times were lower for the rhyme judgement task than for the lexical decision task, especially for non-word targets.

Aphasic Subjects: Non-Fluent Aphasic Subjects (NFAS) and Fluent Aphasic Subjects (FAS)

Since error rates were of interest in both aphasic groups, no criterion response accuracy was set for inclusion in the analyses and no subjects, therefore, were eliminated on the basis of high error rates. Items that were eliminated from control group analyses because of their high rate of misperception by control subjects were eliminated from analysis of the aphasic data as well.

As with the control group, reaction times were recorded for correct responses only, and were adjusted by 20 msec to compensate for the time between the tone's activation of the timer and the onset of the target. Mean reaction times and standard deviations were calculated for reaction times in each prime condition, with the exception of the filler condition (FIL), and outliers were eliminated as they were for the control group data. For the aphasic groups, statistical analyses were performed only on the subject data; no item analyses were conducted. As with control subjects, error rates and reaction times were analyzed separately for word and non-word targets for each task and for each group.

NFAS: Lexical Decision Task - Word Targets

The overall error rate for word targets in the lexical decision task was 11.1% for non-fluent aphasic subjects. Error rates for each condition are shown in Table 10. The lowest error rates occurred in the ID and WR conditions, while the highest error rate occurred in the NWNR condition; NWR and WNR conditions resulted in intermediate error rates of identical value. For both word and non-word primes, error rates were greater for non-rhyming than for rhyming pairs.

Table 10: NFAS - Reaction Times (msec) and Error Rates (%) for Word Targets in the Lexical Decision Task

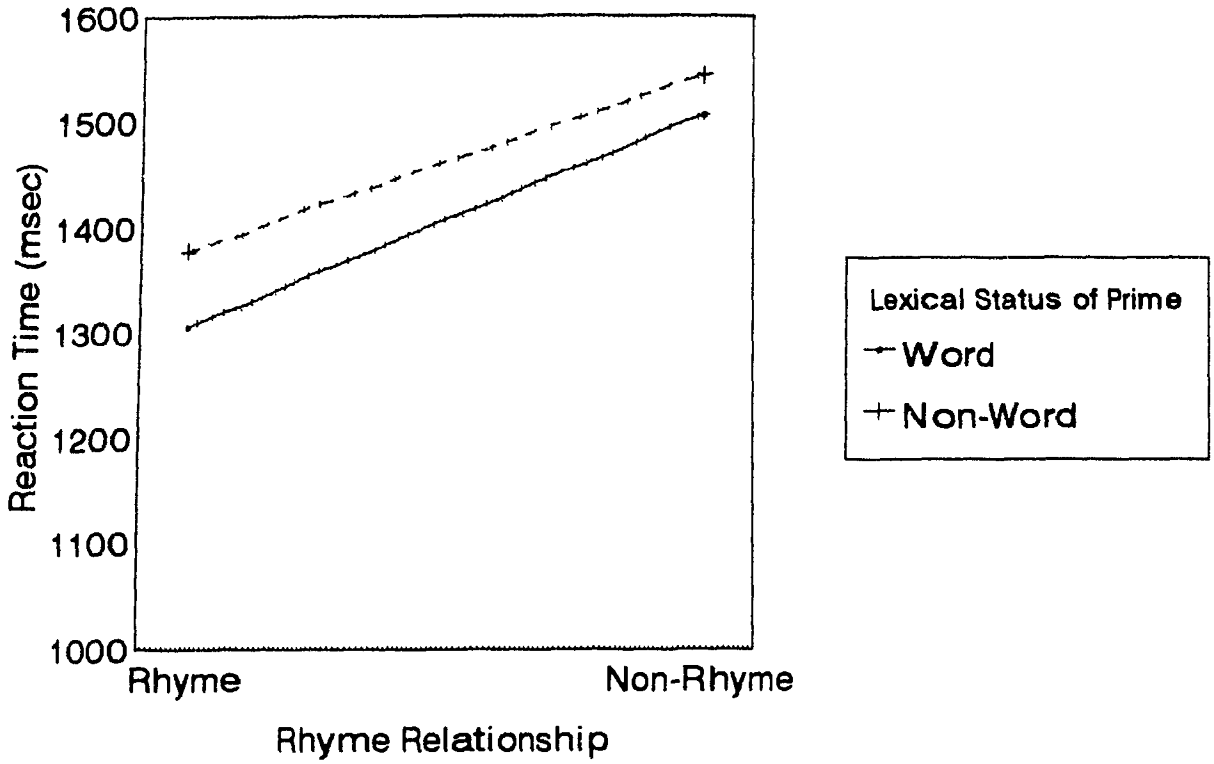
	ID	WR	NWR	WNR	NWNR
NFAS-1	801	933	938	1066	1026
NFAS-2	992	1015	1065	1099	1077
NFAS-3	1125	1216	1224	1454	1245
NFAS-4	1371	1443	1608	1672	1733
NFAS-5	915	1015	1003	1017	965
NFAS-6	1248	1430	1499	1458	1449
NFAS-7	1759	1079	1340	1506	1672
NFAS-8	1116	1197	1261	1284	1201
NFAS-9	1431	1598	1887	2223	2730
NFAS-10	1771	1754	1813	2094	2315
NFAS-11	1383	1675	1512	1690	1568
MEAN	1265	1305	1377	1506	1544
STD	303	276	302	378	530
ERRORS	8.6%	8.6%	12.1%	12.1%	14.1%

Mean reaction times for each subject in each prime condition are presented in Table 10. The overall means show the same pattern as that shown by control subjects for word targets in the lexical decision task: faster RTs for the three rhyming conditions than the two non-rhyming conditions. The individual means of seven of the subjects show the same pattern. Overall, and for all but one of the subjects (NFAS-7), the ID condition yielded the fastest RTs.

Reaction times to word targets were analyzed statistically through one-way and two-way ANOVAs, as they were for the control group. A repeated measures one-way ANOVA comparing the conditions ID, WR, and WNR revealed a significant effect of phonological relationship among word pairs [$F(2,20) = 6.70$]. Post-hoc Neuman-Keuls comparisons showed that the difference between ID and WR conditions was not significant, but that the ID condition and the WR condition were both significantly faster than the WNR condition. This pattern is the same as that found for control subjects.

The effects of rhyme relationship (not including the ID condition) and lexical status of prime are shown in Figure 5. A facilitory effect of rhyme is clearly evident for both word and non-word primes, and a slight advantage of words over non-words is apparent. A two-way analysis of variance confirmed a main effect of rhyme [$F(1,10) = 6.69$], but no significant effect of lexical status of prime, as for the

Figure 5: NFAS - Rhyme and Lexical Status of Prime Effects for Word Targets in the Lexical Decision Task



control group. Unlike the control group, no significant interaction was revealed, thus no post-hoc tests were conducted.

NFAS: Lexical Decision Task - Non-Word Targets

The overall error rate of aphasic subjects to non-word targets was 22.2%. As shown in Table 11, the ID condition's error rate is about ten percentage points below the error rates in the other conditions, which are all approximately equal.

Overall group means and individual subject mean RTs for each condition are also listed in Table 11 for non-word targets. The lowest overall mean RT in the ID condition

Table 11: NFAS - Reaction Times (msec) and Error Rates (%) for Non-Word Targets in the Lexical Decision Task

	ID	WR	NWR	WNR	NWNR
NFAS-1	889	1130	1111	1045	111[illegible]
NFAS-2	1142	1321	1277	1368	1[illegible]58
NFAS-3	1186	1232	1228	125[illegible]	[illegible]
NFAS-4	2163	2256	1830	2106	21[illegible]
NFAS-5	1010	1163	1233	1150	1214
NFAS-6	1107	1463	1317	1290	1442
NFAS-7	176[illegible]	2246	2081	1638	2151
NFAS-8	1185	1415	1577	1387	1530
NFAS-9	1828	1874	2349	1660	2089
NFAS-10	3277	2920	2691	3636	3837
NFAS-11	1886	2085	2409	1815	2186
MEAN	1585	1737	1742	1666	1869
STD	670	554	539	691	734
ERRORS	14.1%	24.2%	24.8%	24 2%	23.7%

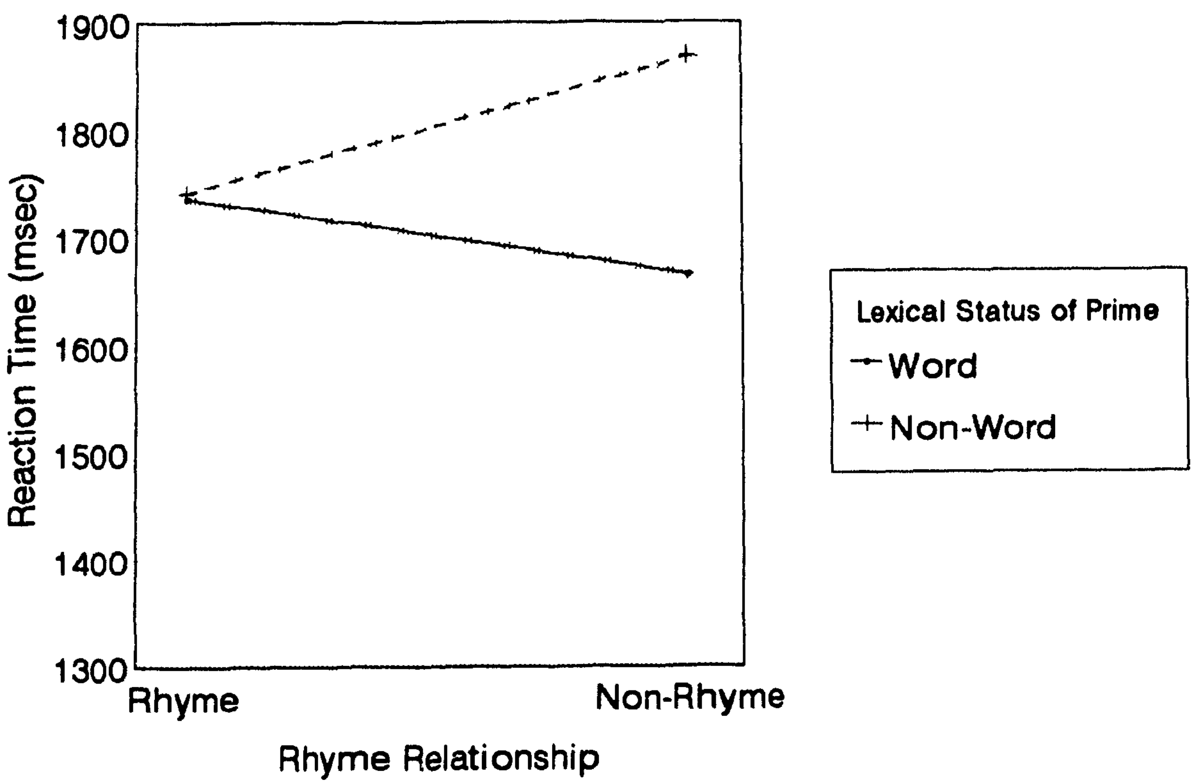
corresponds with the lowest error rate in that condition.

The overall pattern shows word primes to be faster than non-word primes, just as normal subjects showed for non-word targets in the lexical decision task. However, only four of the non-fluent aphasic subjects demonstrated the overall pattern, indicating a great deal of variability in individual subject performance. For non-word primes, the expected advantage of rhyming over non-rhyming pairs appeared, but for word primes, rhyming pairs were actually responded to more slowly overall than non-rhyming pairs.

A one-way ANOVA including ID, NWR, and NWNR conditions showed a significant effect of phonological relationship [$F(2,20) = 4.92$], as shown in the control group. Unlike the control subjects, however, Neuman-Keuls tests revealed no significant differences between ID and NWR conditions. Only the difference between maximally phonologically related (ID) and minimally phonologically related (NWNR) pairs was significant.

The effects of rhyme (excluding the ID condition) and lexical status of prime are shown in Figure 6. Non-word targets were responded to more quickly when preceded by word primes than when preceded by non-word primes. A rhyming effect is apparent, but, as noted earlier, the patterns for word and non-word primes are distinctly different.

Figure 6: NFAS - Rhyme and Lexical Status of Prime Effects for Non-Word Targets in the Lexical Decision Task



Results of a two-way ANOVA (rhyme relationship x lexical status of prime) revealed that the main effects of neither the rhyme relationship nor the lexical status of prime were significant, but the interaction between these two factors was significant [$F(1,10) = 7.87$]. Control subjects also showed an interaction between the two variables, albeit only marginally significant. The lack of a significant effect of lexical status of prime for non-fluent aphasic subjects is, however, a departure from the control group findings with non-word targets.

Neuman-Keuls tests were conducted to explore the interaction. Rhyming pairs were significantly faster than non-rhyming pairs with non-word primes (NWR vs NWNR), unlike the results for the control group. Similar to the control subjects, no such difference was found with word primes (WR vs WNR). Word primes resulted in significantly shorter reaction times than non-word primes with non-rhyming pairs (WNR vs NWNR), but not with rhyming pairs. (For control subjects, the lexical effect was significant for both rhyming and non-rhyming pairs.) No other significant differences were found.

NFAS: Lexical Decision Task - Summary

A significant effect of phonological relationship was found for both word and non-word targets. As with the control subjects, post-hoc tests showed this to be primarily a rhyme effect for word targets, and primarily an identity effect for non-word targets. The effect of identity was not as strong for non-fluent aphasic subjects as for control subjects, since no significant difference was found between identical and rhyming non-word pairs for non-fluent aphasic subjects. Rhyming word and non-word primes significantly facilitated "yes" responses (i.e. to word targets), but not "no" responses (i.e. to non-word targets). Both of these findings were also found for the control subjects. The lexical status of the prime had no effect on word or non-word target responses, while it had a significant effect on non-word target responses for control subjects. Similar to the results for control subjects, error rates and reaction times were generally lower for word targets than for non-word targets. For both word and non-word targets, reaction times and error rates were consistently higher for non-fluent aphasic subjects than for control subjects.

NFAS: Rhyme Judgement Task - Word Targets

Non-fluent aphasic subjects obtained an overall error rate of 7.6% on the word targets of the rhyme judgement task, indicating that they were able to accurately identify rhyme relationships. As shown in Table 12, their accuracy was greater for the three rhyming conditions than for the two non-rhyming conditions. Among the rhyming conditions, ID primes were most accurate, then WR primes, then NWR primes. Comparing the two non-rhyming prime conditions, word primes were again more accurate than non-word primes.

Individual and overall subject mean reaction times are also presented in Table 12. Corresponding to the error

Table 12: NFAS - Reaction Times (msec) and Error Rates (%) for Word Targets in the Rhyme Judgement Task

	ID	WR	NWR	WNR	NWNR
NFAS 1	692	855	773	1077	964
NFAS-2	870	997	1065	1015	996
NFAS-3	1280	1307	1259	1436	1436
NFAS-4	1520	1337	2295	3043	2269
NFAS-5	753	810	834	1004	966
NFAS-6	968	914	1015	1174	1108
NFAS-7	1126	1686	1627	1299	1394
NFAS-8	1036	1248	1207	1154	1135
NFAS-9	965	984	1184	1887	1685
NFAS-10	2153	2163	2533	2506	2373
NFAS-11	1233	1501	1506	1713	1392
MEAN	1145	1309	1391	1573	1429
STD	392	439	541	637	474
ERRORS	4.1%	5.5%	6.8%	10.0%	11.4%

rates pattern, the three rhyming prime conditions all yielded shorter mean RTs than the two non-rhyming conditions. Of eleven subjects, however, only five demonstrated this pattern, suggesting a high degree of variability among subjects. Comparing the rhyming conditions, identical primes had shorter RTs than WR primes, which, in turn, were shorter than WNR primes. For non-rhyming conditions, non-word primes yielded shorter reaction times than word primes.

A repeated measures one-way ANOVA conducted on the mean reaction times of conditions ID, WR, and WNR indicated a significant main effect of phonological relationship [$F(2,20) = 7.76$]. Neuman-Keuls tests revealed that the difference between ID and WR prime conditions was not significant, but the differences between ID and WNR, and between WR and WNR conditions were both significant. As with word targets in the LD task, control and non-fluent aphasic groups showed similar effects of phonological relationship.

Figure 7: NFAS - Rhyme and Lexical Status of Prime Effects for Word Targets in the Rhyme Judgement Task

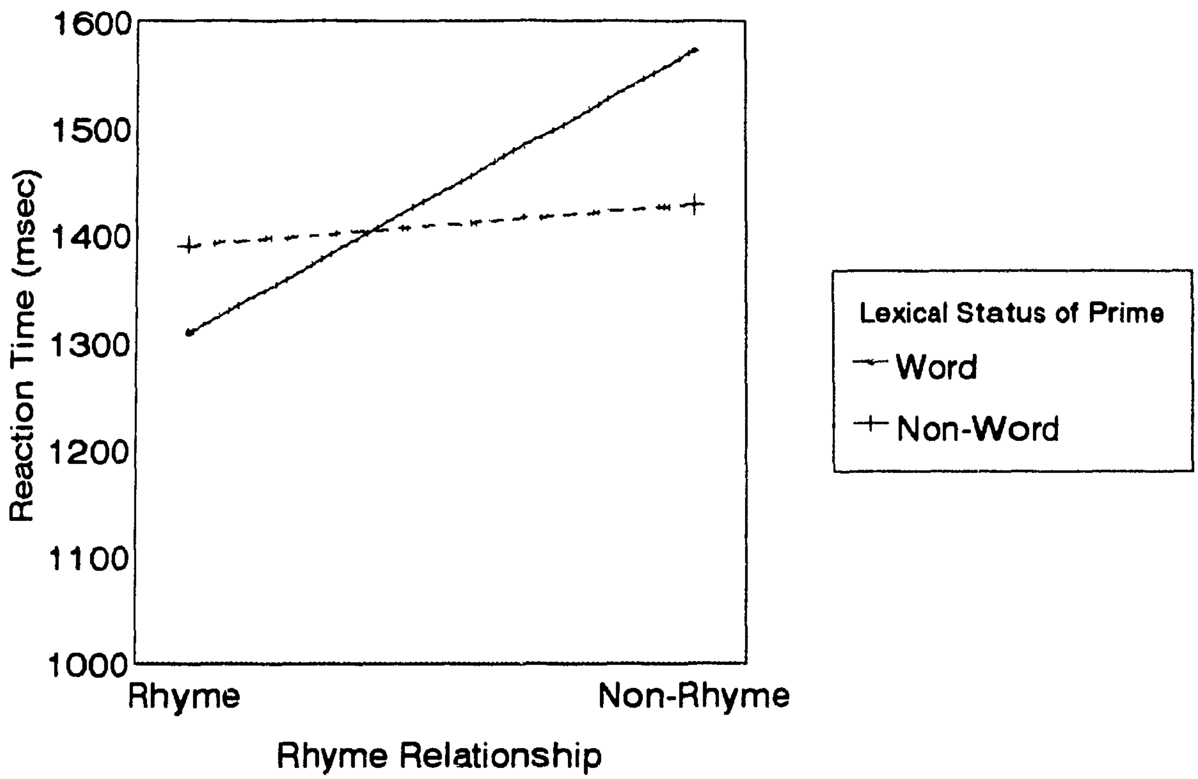


Figure 7 displays the effects of rhyme and lexical status of prime on rhyme judgements with word targets. The figure shows that rhyming pairs were responded to more quickly than non-rhyming pairs, for both word and non-word primes, the difference being much more pronounced for word primes. However, a two-way ANOVA comparing rhyme relationship and lexical status of prime revealed no significant main effects or interactions, whereas for control subjects, a marginally significant effect of rhyme was evident.

NFAS: Rhyme Judgement Task - Non-Word Targets

The overall error rate for non-fluent aphasic subjects in the rhyme judgement task was 6.7% for non-word targets. As with word targets, error rates (displayed in Table 13) were lower for the three rhyming conditions than for the two non-rhyming conditions. The lowest error rate occurred with identity primes, and for both

Table 13: NFAS - Reaction Times (msec) and Error Rates (%) for Non-Word Targets in the Rhyme Judgement Task

	ID	WR	NWR	WNR	NWNR
NFAS-1	694	955	763	970	957
NFAS-2	833	1044	953	1078	1021
NFAS-3	1196	1382	1405	1425	1354
NFAS-4	1571	2861	2379	2352	2565
NFAS-5	747	848	857	1027	1015
NFAS-6	1004	1048	1093	1089	1211
NFAS-7	1151	1416	1300	1242	1387
NFAS-8	995	1276	1245	1142	1172
NFAS-9	891	1153	1135	1652	1910
NFAS-10	1812	2401	2166	2660	2280
NFAS-11	1266	1710	1758	1685	1650
MEAN	1106	1463	1369	1484	1502
STD	329	605	501	538	515
ERRORS	4.1%	5.9%	4.6%	10.3%	8.2%

rhyming and non-rhyming primes, non-word primes resulted in lower error rates than word primes.

Individual and overall mean reaction times for each condition are also presented in Table 13. Overall, non-word targets were responded to faster in the rhyming conditions than in the non-rhyming conditions, but this pattern was found for only three of the eleven subjects' individual means. ID primes resulted in the shortest mean RTs, followed by NWR and WR primes, parallel to the pattern of error rates. Contrary to the error rate pattern, however, the mean RT was shorter for WNR primes than NWNR primes.

The reaction time data for ID, NWR, and NWNR conditions were analyzed by a repeated measures one-way ANOVA, which revealed a significant main effect of phonological relationship [$F(2,20) = 13.17$]. Subsequent Neuman-Keuls analyses indicated that the ID condition had significantly shorter RTs than both the NWR and NWNR conditions, but that the NWR and NWNR conditions were not significantly different from each other. Again, this pattern parallels that of the control group.

Figure 8: NFAS - Rhyme and Lexical Status of Prime Effects for Non-Word Targets in the Rhyme Judgement Task

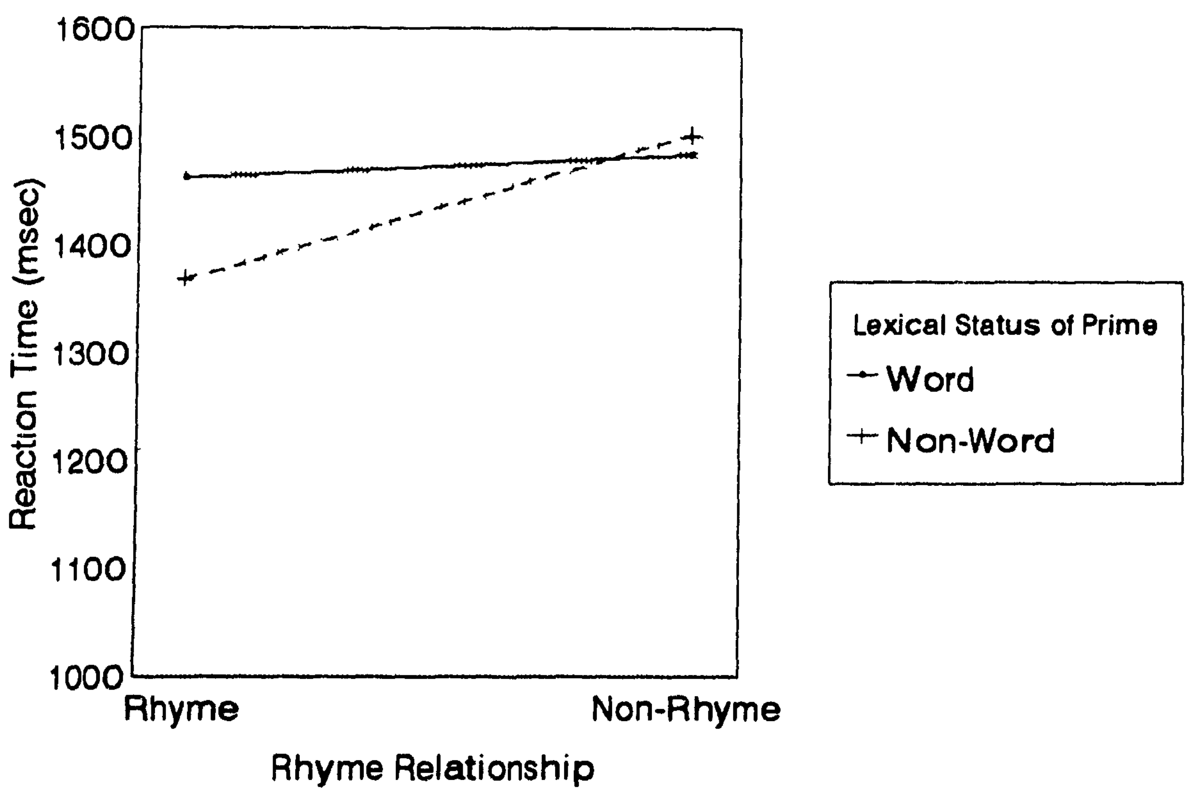


Figure 8 displays the effects of rhyme relationship (excluding ID) and lexical status of prime. There appears to be a facilitory effect of rhyme for both word and non-word primes, that is more pronounced for non-word than word primes. As with word targets, however, a two-way ANOVA (rhyme x lexical status of prime) showed no significant main effects, and no significant interaction between the variables. Similar results were found for control subjects with non-word targets in the RJ task.

NFAS: Rhyme Judgement Task - Summary

Both word and non-word targets showed a significant effect of phonological relationship among primes sharing lexical status with the target. As in the lexical decision task forNFAS and in both tasks for CS, the difference between rhyming and non-rhyming primes was largely responsible for this effect on word targets, while the difference between identical primes and non-identical primes was largely responsible for non-word targets. Neither lexical status of the prime, nor rhyme, had any effect on rhyme judgements with word or non-word targets. The only difference between the rhyme judgement findings for control subjects and non-fluent aphasic subjects was that the finding of a marginally significant rhyme effect for control subjects was not replicated by non-fluent aphasic subjects.

The overall error rate for non-word targets (6.7%) was only slightly smaller than the overall error rate for word targets (7.6%), and reaction times were comparable for both types of targets, as they were for control subjects.

As might be expected, error rates were lower in the rhyme judgement task than in the lexical decision task for word targets (7.6% and 11.1%, respectively), but more notably for non-word targets (6.7% and 22.2%, respectively). In addition, the reaction times of non-fluent aphasic subjects were considerably shorter in the RJ task than in the LD task for non-word targets, but not for word targets.

FAS: Lexical Decision Task - Word Targets

Fluent subjects had an overall error rate of 14.1% for word targets in the lexical decision task, with the lowest error rate occurring for the identity prime condition, as for control and non-fluent aphasic subjects. The error rates for each condition are provided in Table 14. ID and WR conditions yielded the lowest error rates. The NWR condition yielded a slightly higher error rate than the two non-rhyming conditicns, for which error rates were identical.

Individual and overall mean reaction times are presented in Table 14. The table indicates that the three rhyming conditions yielded shorter mean reaction times than the two non-rhyming conditions but that only three of the nine fluent subjects consistently replicated this overall pattern. Unlike for the other two subject groups, the ID condition did not result in the lowest reaction time. Non-word rhyme primes resulted in slightly faster RTs than word rhyme primes, and non-word unrelated primes resulted in faster RTs than word unrelated primes.

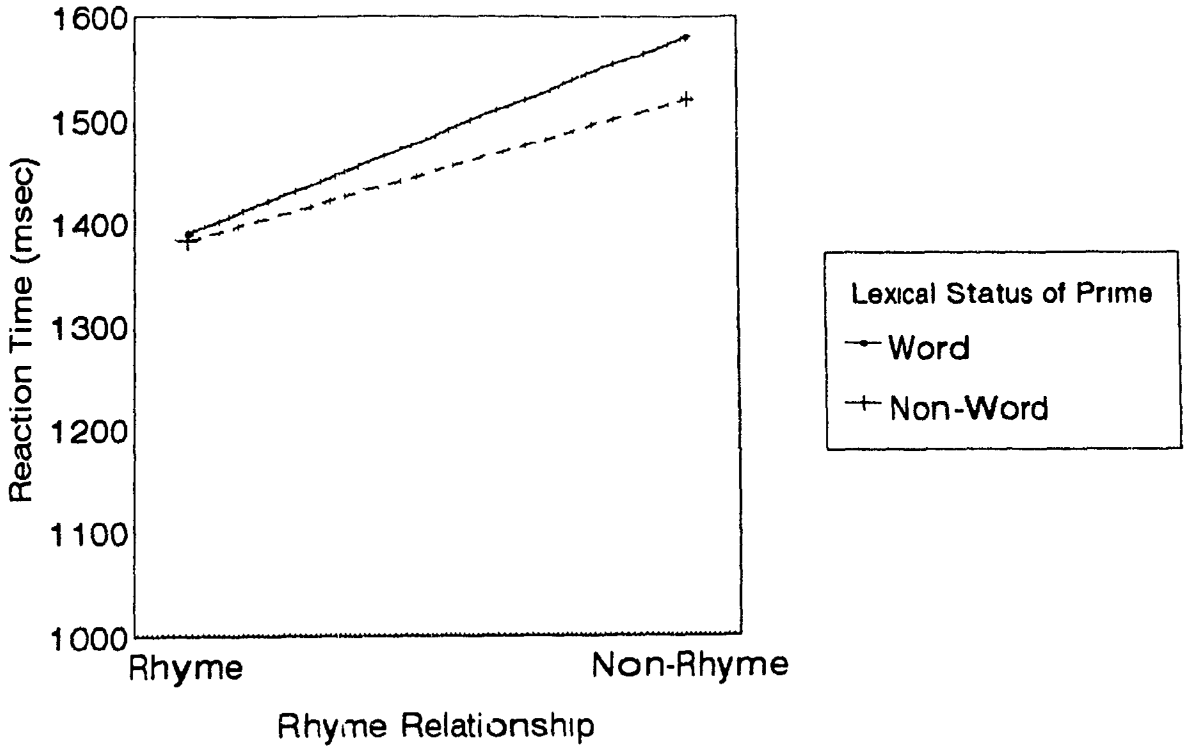
Table 14: FAS - Reaction Times (msec) and Error Rates (%) for Word Targets in the Lexical Decision Task

	ID	WR	NWR	WNR	NWNR
FAS-1	1261	1174	1147	1239	1200
FAS-2	1159	1289	1240	1391	1364
FAS-3	1125	1034	1014	1115	1070
FAS-4	1083	1653	1913	2162	2439
FAS-5	1698	1749	1480	1583	1490
FAS-6	1405	1465	1355	1762	1279
FAS-7	2014	1602	1602	1667	1679
FAS-8	1327	1240	1298	1862	1628
FAS-9	1631	1303	1399	1443	1525
MEAN	1414	1390	1383	1580	1519
STD	293	227	249	307	376
ERRORS	6.8%	10.5%	18.5%	17.3%	17.3%

A one-way ANOVA was conducted on the reaction times to assess the effect of degree of phonological relationship between ID, WR, and WNR primes and targets. No significant effect was revealed, unlike for the control and non-fluent aphasic groups.

Figure 9 shows the effects of the two variables--rhyme relationship (again, excluding the ID condition) and lexical status of prime--on reaction time. It is evident that rhyming pairs resulted in faster RTs than non-rhyming pairs, for both word and non-word primes. A two-way ANOVA (rhyme relationship x lexical status of prime) confirmed that the

Figure 9: FAS - Rhyme and Lexical Status of Prime Effects for Word Targets in the Lexical Decision Task



effect of rhyme was significant [F(1,8) = 6.08] (as for the other two subject groups) despite the finding of no significant effect of phonologicalrelationship in the one-way ANOVA. The effect of rhyme only showed up for the fluent aphasic subjects, then, when word and non-word primes were considered together. There was no significant effect of lexical status of prime, nor was there a significant interaction between the two variables (unlike control subjects, but similar to the non-fluent aphasic subjects).

FAS: Lexical Decision Task - Non-Word Targets

For non-word targets, fluent subjects had a high overall error rate of 31.2%. Error rates for each condition were quite comparable, as may be seen in Table 15.

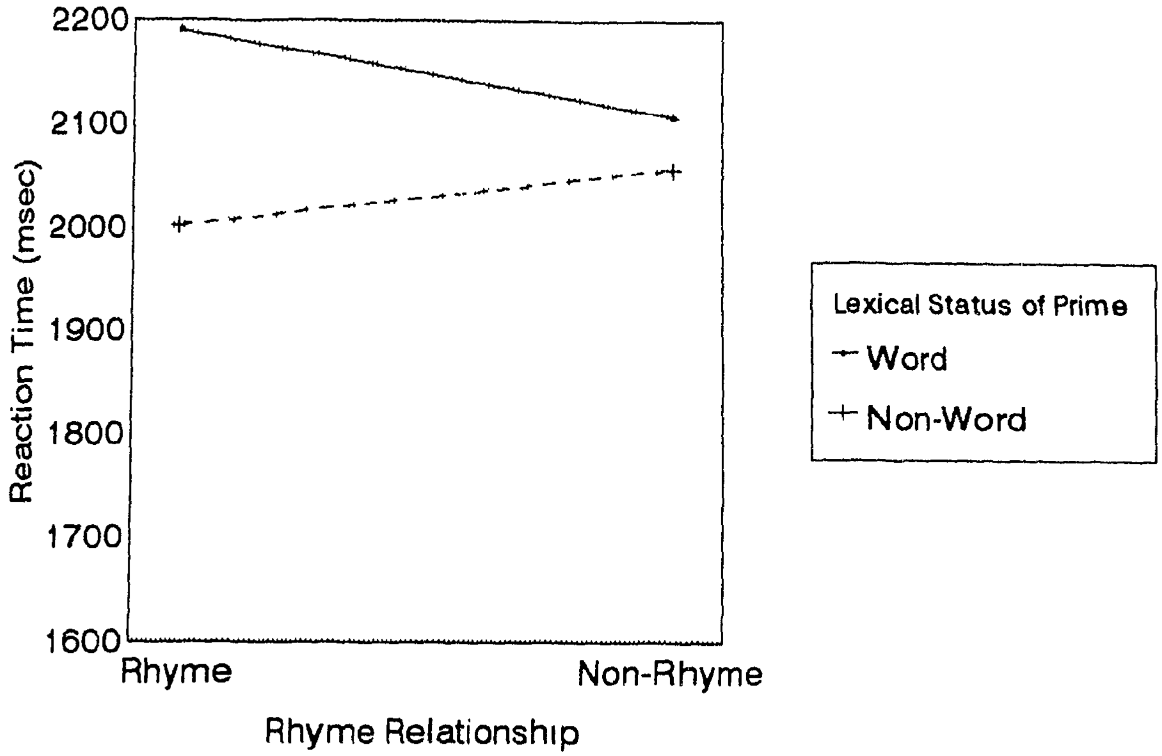
Reaction times, also presented in Table 15, were also high for the non-word targets, with no coherent pattern among conditions. A one-way ANOVA comparing ID, NWR, and NWNR prime conditions revealed no significant effect of phonological relationship. As with word targets, this finding sets the fluent aphasic subjects apart from the non-fluent aphasic and control subjects.

Table 15: FAS - Reaction Times (msec) and Error Rates (%) for Non-Word Targets in the Lexical Decision Task

	ID	WR	NWR	WNR	NWNR
FAS-1	2466	2786	2492	2548	2514
FAS-2	2433	2261	2347	2243	2788
FAS-3	874	1101	1241	1089	1192
FAS-4	2092	2617	2538	2900	1664
FAS-5	1878	1897	2032	1857	1914
FAS-6	2306	2539	2304	1942	2236
FAS-7	2308	2526	2520	2439	2111
FAS-8	1609	1499	1764	1684	1951
FAS-9	2472	2474	1778	2263	2146
MEAN	2049	2189	2002	2107	2057
STD	499	538	424	504	437
ERRORS	30.9%	33.3%	34.6%	27.2%	30.3%

The effects of rhyme relationship (excluding the ID condition) and lexical status of prime are displayed in Figure 10. The graph suggests significant effects of both factors, as well as an interaction between the two factors. However, a two-way ANOVA demonstrated that neither factor nor the interaction were significant. This was in contrast to both control and non-fluent aphasic subject groups, who showed a significant interaction between the two factors.

Figure 10: FAS - Rhyme and Lexical Status of Prime Effects for Non-Word Targets in the Lexical Decision Task



FAS: Lexical Decision Task - Summary

Unlike control subjects and non-fluent aphasic subjects, no significant effect of phonological relationship between prime and target was found for either word targets or non-word targets. However, a significant main effect of rhyme did occur with word targets, but not with non-word targets. Similar to the results for the non-fluent aphasic group, the lexical status of prime did not affect either word or non-word target reaction times. Error rates and reaction times were considerably higher for non-word targets than for word targets. In addition, lexical decision error rates and reaction times were higher for fluent aphasics than for non-fluent aphasic subjects, especially with non-word targets.

FAS: Rhyme Judgement Task - Word Targets

Fluent aphasic subjects, as a group, made 6.6% errors overall on word targets in the rhyme judgement task. Error rates for each condition, presented in Table 16, ranged from no errors in the ID condition to 16.1% errors in the WNR condition. For rhyming pairs, errors rates were slightly lower for word than for non-word primes, while for non-rhyming pairs, errors were considerably higher with word than non-word primes.

Table 16: FAS - Reaction Times (msec) and Error Rates (%) for Word Targets in the Rhyme Judgement Task

	ID	WR	NWR	WNR	NWNR
FAS-1	623	1067	1055	2317	2187
FAS-2	858	1633	2337	1202	1186
FAS-3	754	870	792	796	855
FAS-4	792	912	945	1611	2303
FAS-5	1053	1251	1326	1905	1654
FAS-6	1570	1755	1784	2631	2342
FAS-7	997	979	981	1578	1547
FAS-8	970	1047	959	1317	1308
FAS-9	1033	1182	1149	1278	1048
MEAN	961	1188	1259	1626	1603
STD	254	294	469	543	528
ERRORS	0.0%	4.4%	5.0%	16.1%	7.2%

Table 16 also provides mean reaction times for each subject and overall mean reaction times in each condition. The pattern across conditions was similar to that found for the error rates; the ID condition yielded the lowest RT, and word primes resulted in lower RTs than non-word primes for rhyming pairs, but higher RTs than non-word primes for non-rhyming pairs.

A one-way ANOVA with the three word conditions (ID, WR, WNR) revealed a significant effect of phonological relationship [$F(2,16) = 10.58$]. Post-hoc Neuman-Keuls comparisons showed no significant difference between ID and WR conditions, but significant differences between ID and WNR conditions, and between WR and WNR conditions. This pattern is the same as that shown by both control and non-fluent aphasic groups.

Figure 11: FAS - Rhyme and Lexical Status of Prime Effects for Word Targets in the Rhyme Judgement Task

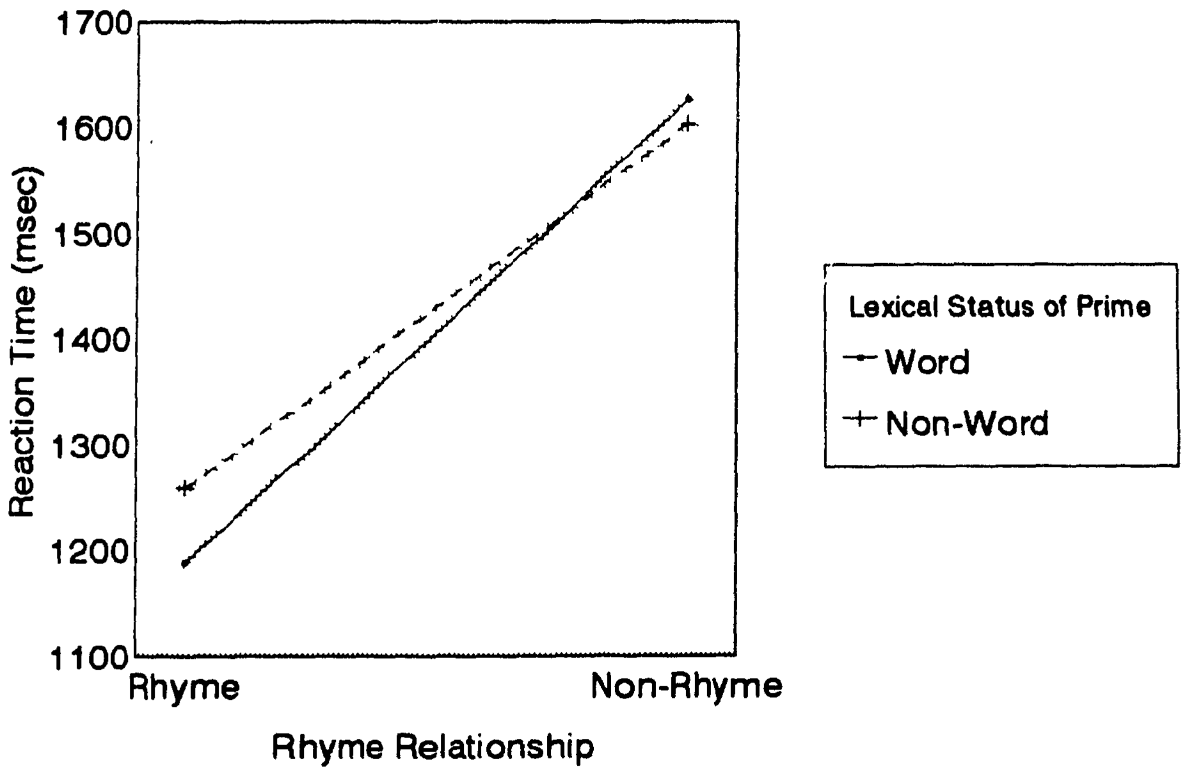


Figure 11 displays the effects of rhyme relationship (excluding the ID condition) and lexical status of prime on the reaction times to word targets. Non-rhyming pairs showed considerably longer RTs than rhyming pairs, with both word and non-word primes, the difference being somewhat greater for words than for non-words. A two-way ANOVA, however, revealed no significant effects of rhyme or lexical status of prime, and no significant interaction between the two variables, as was the case for non-fluent aphasic subjects.

FAS: Rhyme Judgement Task - Non-Word Targets

Error rates for each condition are presented in Table 17. The overall error rate on non-word targets for fluent aphasics was 5.4%. As with word targets, the ID condition had the lowest error rate. Responses in all rhyming conditions were more accurate than in the non-rhyming conditions, as for non-fluent aphasic subjects. Responses to targets preceded by word primes were more accurate than

Table 17: FAS - Reaction Times (msec) and Error Rates (%) for Non-Word Targets in the Rhyme Judgement Task

	ID	WR	NWR	WNR	NWNR
FAS-1	706	1560	1836	1868	2148
FAS-2	981	2599	2288	1169	1272
FAS-3	699	814	931	944	907
FAS-4	795	959	937	1844	2416
FAS-5	1078	1241	1470	1848	1756
FAS-6	1569	2077	1768	2159	2124
FAS-7	918	974	1007	1613	1757
FAS-8	868	1053	1066	1308	1379
FAS-9	959	1369	1198	1282	1220
MEAN	953	1405	1389	1559	1664
STD	248	557	455	379	475
ERRORS	0.6%	2.8%	4.4%	8.3%	11.1%

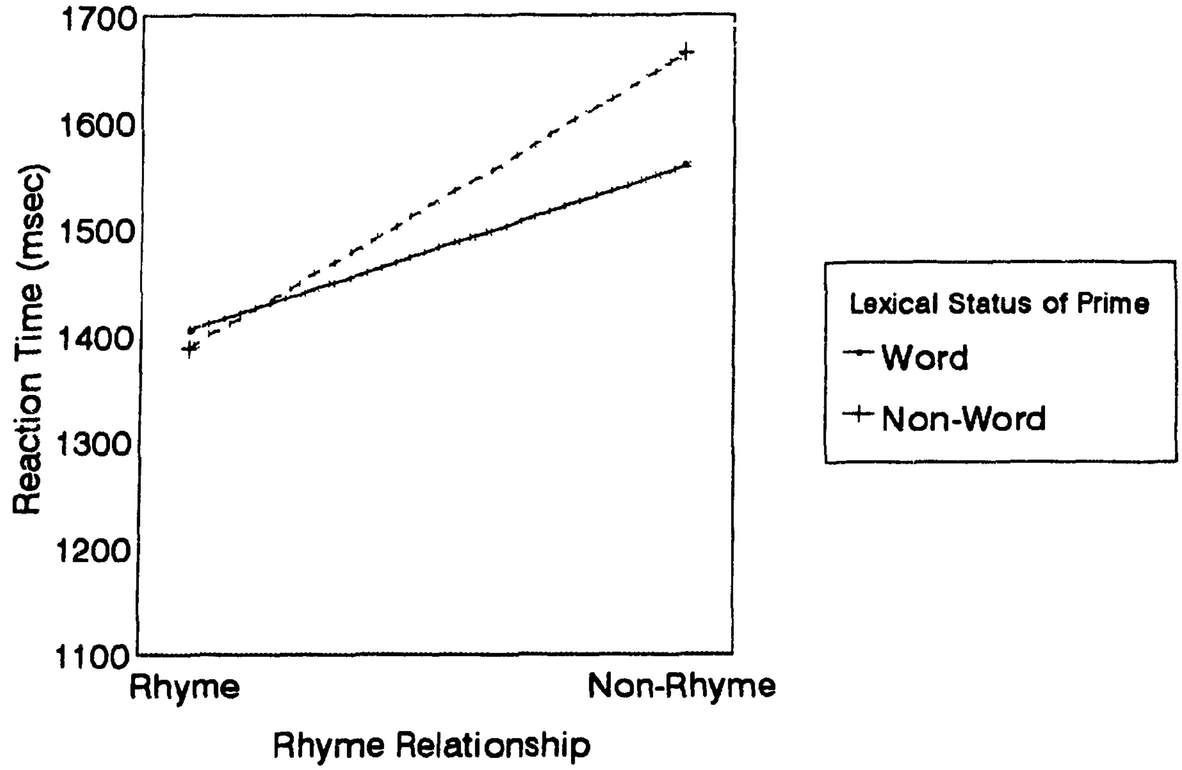
to targets preceded by non-word primes for both rhyming and non-rhyming pairs.

Individual subject and overall mean RTs are presented in Table 17. As with error rates, the lowest reaction time occurred in the ID condition, and the rhyming conditions yielded lower reaction times than the non-rhyming conditions. Word rhyme primes were slower than non-word rhyme primes, but word non-rhyme primes were faster than non-word non-rhyme primes. This pattern parallels the results shown by the non-fluent aphasic group.

A one-way ANOVA including the three non-word prime conditions (ID, NWR, NWNR) revealed a significant effect of prime-target phonological relationship. In post-hoc comparisons, the ID condition was found to be significantly different from both NWR and NWNR conditions, but NWR and NWNR conditions were not significantly different from each other, as was found for control and non-fluent aphasic subjects.

The effects of rhyme relationship (excluding the ID condition) and lexical status of prime are shown graphically in Figure 12. There appears to be an advantage of rhyming over non-rhyming conditions for both word and non-word primes. However, a two-way ANOVA revealed no significant differences, and no significant interaction, similar to the results for control and non-fluent aphasic groups.

Figure 12: FAS - Rhyme and Lexical Status of Prime Effects for Non-Word Targets in the Rhyme Judgement Task



FAS: Rhyme Judgement Task - Summary

Both word and non-word targets showed a significant effect of phonological relationship between prime and target, as in control and non-fluent aphasic groups. As for the other groups, the effect was due to a significant rhyme/non-rhyme difference for word targets, and a significant identity/non-identity difference for non-word targets. No significant main effects of rhyme or lexical status of prime and no significant interactions were revealed for either word targets or non-word targets, as in the non-fluent aphasic group. A marginally significant effect of rhyme emerged for the control group; otherwise results of the rhyme judgement task were similar for all three groups.

There appears to be little difference between word targets and non-word targets either in overall error rates or mean reaction times. Error rates were generally higher and reaction times longer in the lexical decision task than in the rhyme judgement task. These differences were especially noticeable with non-word targets. For fluent aphasic subjects, error rates and reaction times in the rhyme judgement task were comparable to those shown by non-fluent aphasic subjects.

Overall Summary

Lexical Decision Task

For ease of comparison, the mean reaction times in each condition for all three groups were re-plotted on a single graph. Figure 13 illustrates graphically the pattern of response times to word targets in the lexical decision task. Similar patterns can be seen in the three groups, except for a reversal in one condition for the non-fluent aphasics: the mean NWNR prime reaction time is higher than the mean WNR prime, whereas it is lower for the fluent aphasic and control groups. The difference between these two conditions is significant only for the control group.

Figure 14 shows the patterns of reaction times across conditions of non-word targets for all the groups. Control subjects and non-fluent aphasic subjects demonstrated

Figure 13: Reaction Times (Prime Condition X Subject Group) for Word Targets in the Lexical Decision Task

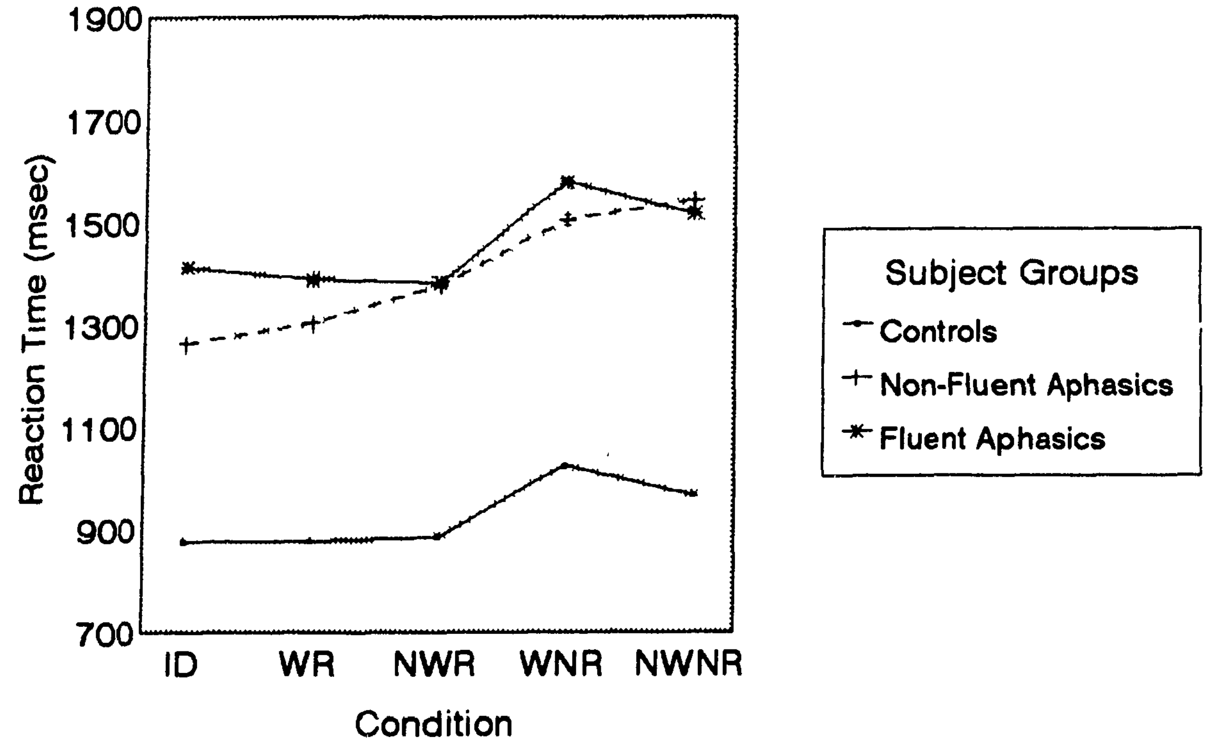
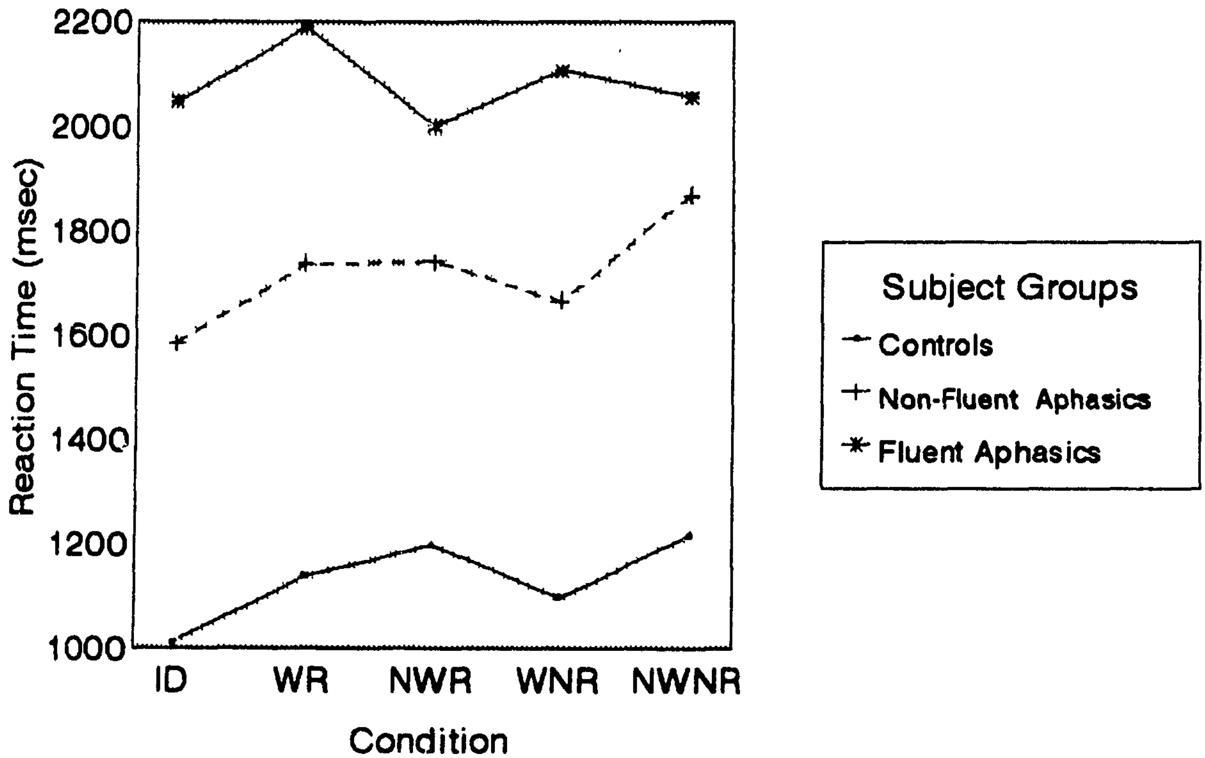


Figure 14: Reaction Times (Prime Condition X Subject Group) for Non-Word Targets in the Lexical Decision Task



remarkably similar response time patterns, while fluent aphasic subjects showed reversals in the direction of differences between word and non-word primes (word primes yielded slower instead of faster RTs than non-word primes). It is immediately apparent that the aphasics' reaction times are considerably slower than those of the control subjects and that, for non-word targets, fluent aphasics responded more slowly than non-fluent aphasics.

Rhyme Judgement Task

Figure 15 displays the mean rhyme judgement reaction times to all prime conditions of word targets for each group. The pattern of reaction times was quite similar for all three

Figure 15: Reaction Times (Prime Condition X Subject Group) for Word Targets in the Rhyme Judgement Task

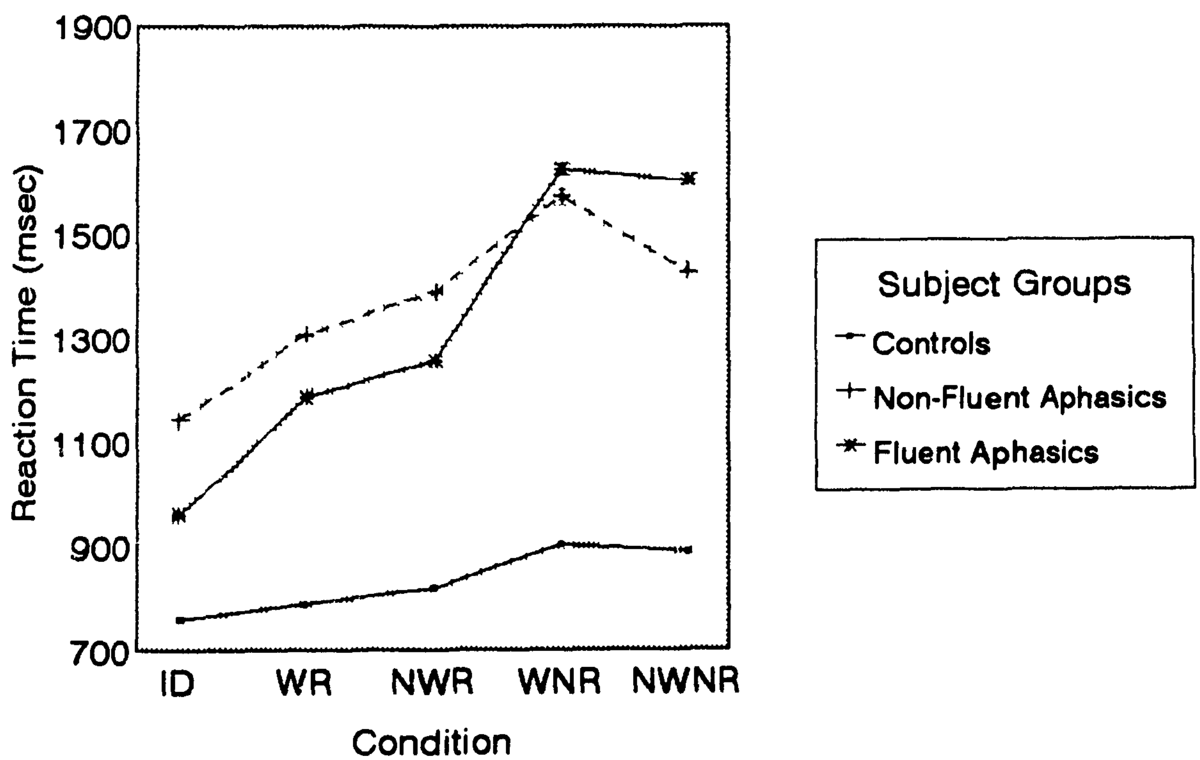
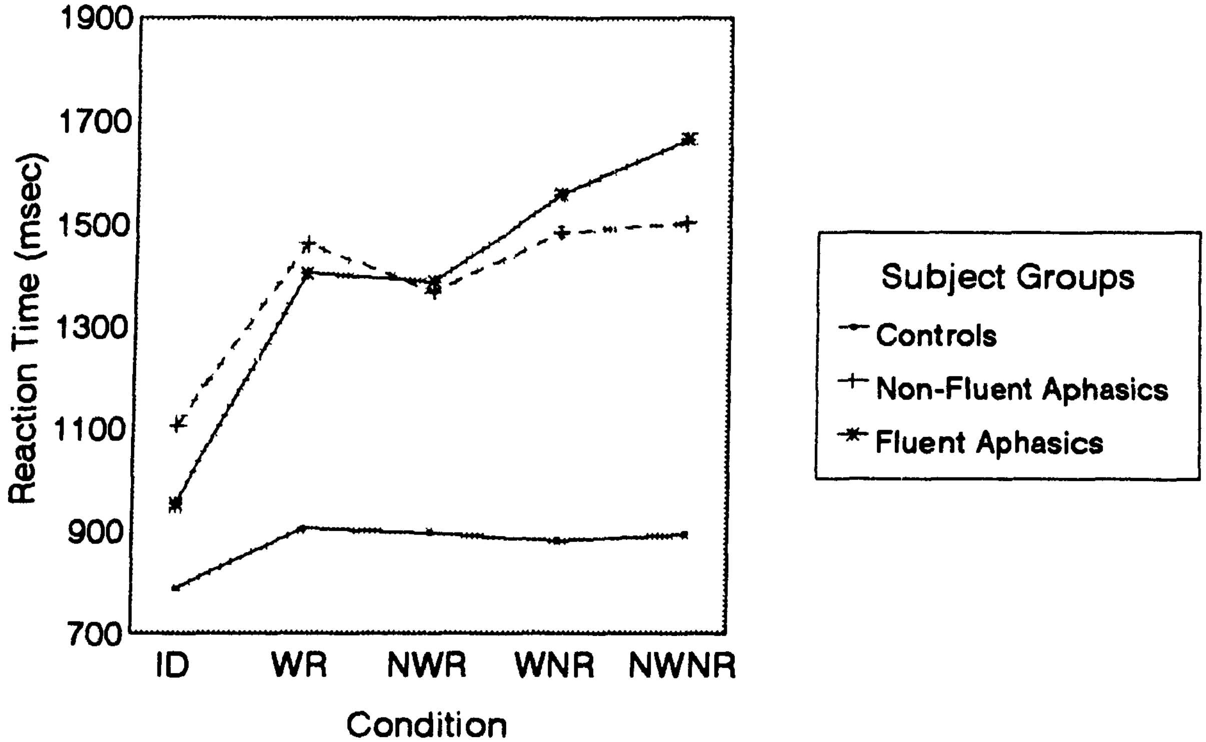


Figure 16: Reaction Times (Prime Condition X Subject Group) for Non-Word Targets in the Rhyme Judgement Task



groups, reflecting the facilitative effect of rhyme for word targets that was revealed by one-way ANOVAs for all three groups. As in the lexical decision task, reaction times were higher for aphasic than control groups. However, the difference was less than it was in the LD task.

Figure 16 shows the reaction time patterns with non-word targets in the RJ task for all three groups. The graph reflects the facilitory effect of identity revealed by the one-way ANOVA for each group. As with word targets, reaction times of the aphasic groups were markedly higher than those of the control group. Unlike the LD task, fluent aphasic subjects did not exhibit the increased difficulty with non-word targets compared to word targets.

DISCUSSION

The present experiment provides strong support for the existence of phonological, specifically rhyming, relationships within the lexicon. Although these connections appear to be preserved to some extent in aphasia, there is evidence of differences between the phonological processing of normal and aphasic subjects, and between fluent and non-fluent aphasic subjects.

In the lexical decision task, responses to word targets were significantly facilitated by rhyming primes for all three subject groups. This result supports Burton's (in press) finding of rhyme facilitation with normal subjects. Like Burton's results, reaction times to rhyming pairs in the current experiment were faster than reaction times to non-rhyming pairs for both word and non-word primes for all three groups (as shown in Figures 1, 5, and 9). The facilitation of word targets from word primes may occur at a lexical level, by means of a spreading activation mechanism acting directly between lexical entries, or it may occur at a sub-lexical level, by means of the activation of sub-lexical components (e.g. phonemes) common to the prime and the target. For non-word primes, only the latter process, which Burton referred to as a "physical matching" process, can account for the facilitation because non-words presumably have no lexical entries.

The control subjects exhibited more rhyme facilitation for word primes than for non-word primes, as demonstrated by the significant interaction between the lexical status of the prime and the rhyming relationship. It appears that normal subjects processed word primes differently from non-word primes. Perhaps word primes provided facilitation at a lexical level, and non-word primes at a sub-lexical level. One might hypothesize, then, that lexical facilitation is greater than sub-lexical facilitation, or, alternatively and perhaps more likely, that both are at work with rhyming word primes, providing more facilitation overall than the sub-lexical facilitation alone provided by rhyming non-word primes. Aphasic subjects, for whom no interaction was found, may be processing the phonology of both word and non-word primes sub-lexically.

When the lexical status of the prime was controlled by comparing only word/word pairs, fluent and non-fluent aphasic subjects showed different results. For control subjects and non-fluent aphasic subjects, responses to word targets were facilitated by identical or rhyming word primes, as might be expected given the overall rhyme facilitation found for these groups. Fluent aphasic subjects, however, showed no such facilitation of phonological similarity between word pairs, despite the rhyme facilitation they showed when word and non-word primes were considered together. Perhaps this insensitivity of fluent aphasics to the phonological relationship between word pairs indicates a disruption in the spread of activation between phonologically related items in the lexicon. The overall rhyme facilitation found for this group when non-word primes were included must be attributed, then, to sub-lexical priming. Apparently, the facilitory effect of rhyme is less robust for this group, and only shows up when word and non-word primes are considered together.

In addition to the facilitory effect of rhyme, Burton (in press) found that lexical decisions made by normal subjects to word targets were facilitated more by identical primes than by rhyme primes; somewhat unexpectedly, this finding was not replicated in the present experiment. Several possible explanations are offered below. Purely sub-lexical priming for word primes would predict that identical primes would provide greater facilitation than rhyming word primes, since all of the target's phonemes would have been activated by the prime, instead of two out of three phonemes activated by rhyming primes. Lexical priming by spreading activation would also predict more identity than rhyme priming; a target following an identity prime would already be fully activated, while the activation spreading to a rhyming target would be weaker than the original activation (Collins & Loftus, 1975). However, one could attribute the non-significant difference between ID and WR primes in the present experiment to the interaction of decay and spreading activation. As activation spreads from BAT to CAT, for example, the original activation of BAT is beginning to decay; thus the subsequent recognition of CAT would be as facilitated as the subsequent recognition of BAT.

This hypothesis is made more tenable by the fact that the control subjects in the present experiment were age-matched to the aphasic patients. In contrast, the subjects in Burton's investigation were college-age individuals. It is possible that activation of lexical items decays more rapidly for older subjects, or that the older subjects have a limitation in speed of processing which was reached in the WR condition (Salthouse, 1988). In other words, word rhymes facilitated responses as much as was possible for these subjects, so that identity primes could not speed up reaction times any further.

For control subjects, non-word primes resulted in shorter reaction times than word primes for non-rhyming pairs, but not for rhyming pairs. Burton (in press) also found that word targets were responded to faster after an unrelated non-word prime than after an unrelated word prime. This non-word advantage for unrelated pairs could be the result of an automatically occurring and time-consuming process of lexical activation of word primes, from which activation would automatically spread to phonologically related words in the lexicon, inhibiting the processing of the unrelated target. Non-word primes would be less likely to quickly activate multiple phonologically related lexical items because they, themselves, have no lexical entries.

Another possibility is that there is an automatically occurring post-access check for semantic relatedness between the prime and the target (Balota & Lorch, 1986) that inhibits or slows responses to semantically unrelated pairs (corresponding to the word/word pairs in the present experiment). Tanenhaus et al. (1980) suggest that semantic processing cannot be suppressed, even when it interferes with the task, such as in colour-naming (Stroop) experiments. Such a check would only occur with word/word pairs, since no semantic relationship is possible between a word and a non-word, or two non-words. This could account for the slower reaction times to word/word pairs relative to non-word/word pairs.

For rhyming word/word pairs, however, any delay or inhibition caused by the prior processing of a word prime would be offset by the facilitation due to spreading activation between the lexical nodes for the prime and the target, which would not occur for non-word rhyming primes. Thus, the non-word advantage found for non-rhyming pairs would not emerge for rhyming pairs, as was shown for the control subjects.

In contrast to the results for normal control subjects, neither of the aphasic groups demonstrated a difference in the amount of facilitation to word targets provided by word and non-word primes. As noted above, these findings suggest that facilitation at a lexical level may not play a significant role for aphasic subjects; for them, the rhyme facilitation for both word and non-word primes may occur solely at a sub-lexical level. With non-word targets, control subjects showed no facilitory effect of rhyme. The only facilitation possible for non-word targets is at a sub-lexical level; such facilitation may not have been strong enough to have a significant effect on reaction times for the control group. Assuming that the lexicon must be exhaustively searched prior to an accurate "no" response, whether or not the prime and target are related, sub-lexical activation may have decayed too much to have an effect on response times. However, Burton (in press) found consistent rhyme priming for non-word/non-word pairs, and some evidence for priming of rhyming word/non-word pairs. The difference in subject population alluded to earlier may explain, in part, the discrepancy between Burton's findings and those of the current experiment.

Similar to the normal subjects, neither aphasic group showed facilitory effects of rhyme (except for a significant effect of rhyme for non-word/non-word pairs shown by non-fluent aphasic subjects). The lack of overall rhyme facilitation effects may be due to the fact that, for all three groups, rhyme trends occured in opposite directions for word and non-word primes. When both primes and targets were non-words, rhyming pairs yielded shorter RTS than non-rhyming pairs; however, for word/non-word pairs, the rhyming condition yielded longer RTs than the non-rhyming condition.

For non-word/non-word pairs only, responses of the control subjects were facilitated with identical primes as compared to rhyming and non-rhyming primes, consistent with Burton's (in press) results. These findings are in keeping with the hypothesis formed earlier that identity primes should provide more facilitation than rhyme primes at a sub-lexical level because they share more phonological information with the target. For non-fluent subjects identical non-word pairs were facilitated only relative to non-rhyming non-word pairs, suggesting a less robust effect of identity than that shown by control subjects. Fluent aphasic subjects, for whom no facilitory effects of phonological similarity were found, appeared to be insensitive to the phonological relationship between non-words. Perhaps any sub-lexical rhyme facilitation effects, such as those suggested with word targets, were lost in the long reaction times of the fluent aphasic subjects to non-word targets.

For control subjects the lexical status of the prime influenced reaction times to non-word targets. They responded faster when the target was preceded by a word prime than by a non-word prime. This word facilitation was greater for non-rhyming pairs than for rhyming pairs, as illustrated by a marginally significant interaction between the two variables. Although Burton did not statistically test the effect of the lexical status of the prime for non-word targets, her data also reveal a word-prime advantage for non-rhyming pairs with normal subjects.

Non-fluent aphasic subjects also showed an advantage of word primes over non-word primes for non-rhyming pairs, but not for rhyming pairs, as reflected in the significant interaction between lexical status of prime and rhyme relationship. For fluent aphasic subjects, on the other hand, lexical status of prime had no significant influence on reaction times to non-word targets.

This pattern suggests that control subjects and non-fluent aphasic subjects were processing word and non-word primes differently, at least for non-rhyming pairs. The word-prime advantage found for non-word targets calls into question the hypothesis suggested earlier that lexical processing of word primes delays target processing. It may simply be that the match in lexical status for non-word/non-word pairs interfered with "no" responses. (This would predict that word/word pairs would facilitate "yes" responses, but for word pairs, other lexical processing factors seem to be at work, as discussed above.) Fluent aphasic subjects apparently were not sensitive to lexical status relationships between the prime and the target, providing further evidence that they were processing both types of primes sub-lexically.

As expected, lexical decision reaction times were higher with non-word targets than with word targets for all three groups. "No" responses are generally assumed to take longer because the lexicon must be exhaustively searched, or all possibilities eliminated, before an item can be decisively labelled a non-word. Both groups of aphasic subjects took longer than control subjects to identify targets as words or non-words. In addition, fluent aphasic subjects took longer than non-fluent aphasic subjects to identify non-word targets. Apparently fluent aphasic subjects had more difficulty searching the lexicon and eliminating word candidates in order to make a non-word lexical decision.

Overall error rates on lexical decisions for non-word targets were about double those for word targets for all three groups of subjects. Non-fluent aphasic subjects made more lexical decision errors than control subjects, and fluent aphasic subjects made more errors than non-fluent aphasic subjects on both word targets and non-word targets.

In the rhyme judgement task, only control subjects showed a marginal overall rhyme facilitation of word targets with word and non-word primes, in contrast to the strong rhyme facilitation effects found for word targets in the lexical decision task for all groups. Because the rhyme judgement task draws attention to the relationship that exists between the test stimuli, it may be that the automatic nature of the facilitation is lost. During a lexical decision task, rhyme facilitation can be assumed to occur automatically, since it occurs without the subjects' intention while they focus on the lexical judgement required. During a rhyme judgement task, however, subjects are required to make a conscious decision about the rhyme relationship between the prime and the target. Automatic facilitation may still occur, but the measurement of this facilitation may be confounded by post-access decision processes involved in the rhyme judgement itself.

When only word/word pairs were considered, rhyme judgements for all three groups were facilitated by a rhyme relationship. This facilitation, however, may also be attributed to a reaction time advantage of "yes" responses over "no" responses. Both types of "yes" responses, identical and rhyming word pairs, were equally facilitory of rhyme judgements, compared to "no" responses for non-rhyming word pairs.

The lexical status of the prime did not influence rhyme judgments with either word or non-word targets. It is possible that focussing the subjects' attention overtly on the rhyming relationship between primes and targets encouraged sub-lexical processing; no lexical processing was necessary to meet the task requirements. This may also explain the similarity in performance among the three groups, since differences between the groups in the lexical decision task were, for the most part, attributed to various lexical effects exhibited by the normal subjects, but not by the aphasic subjects.

With non-word targets, results were similar for all three groups: Rhyme judgements were not facilitated by rhyme or lexical status of prime for any of the groups, but were facilitated by identity for all groups, relative to rhyming and non-rhyming non-word pairs. This facilitation cannot be attributed to the difference between "yes" and "no" responses, because identical non-word pairs provided greater facilitation than rhyming non-word pairs while rhyming non-word pairs provided no greater facilitation than unrelated non-word pairs. Although lexical status of the prime per se had no effect on rhyme judgements, it appears that the lexical status of the pair is important. For word pairs, identity and rhyme relationships facilitated rhyme judgements, while only identity was facilitory for non-word pairs.

Reaction times in the rhyme judgement task were higher for both groups of aphasic subjects than for control subjects with both word and non-word targets, indicating that they required longer processing time in order to make rhyme judgements. There was no noticeable RT difference between word targets and non-word targets for any of the groups, as there was for lexical decisions. But, as noted earlier, for rhyme judgements it was not the lexical status of the target which determined the response. There was a reaction time difference between rhyming ("yes" response) pairs and non-rhyming ("no" response) pairs. As in the lexical decision task, fluent aphasics took longer than non-fluent aphasics to make a "no" response. Differences between the aphasic groups, however, were not nearly so marked in the rhyme judgement task as they were in the lexical decision task.

Error rates were also higher for the two aphasic subject groups than for the control group, but the difference was only noticeable for the non-rhyming conditions, suggesting a small "yes" response bias. However, aphasic subjects made many fewer rhyme judgement errors than lexical decision errors, presumably because the rhyme judgement task could be accomplished without accessing the lexicon and was, therefore, easier for them than the lexical decision task.

The results of the present experiment indicate that the phonological lexical structure is virtually intact for non-fluent aphasic subjects, who showed rhyme facilitation effects similar to the control subjects in the lexical decision task. There is evidence that non-fluent aphasic subjects had some difficulty with phonological processing, since their priming results were less robust than those of the control subjects. Certainly, their processing was slower and less accurate than that of the normal subjects. Results were less consistent for fluent aphasic subjects, who showed limited evidence of rhyme priming in the lexical decision task. It may be that fluent aphasic subjects relied entirely on sub-lexical facilitation, since they showed little rhyme facilitation, and no lexical status of prime effects. Furthermore, they took longer and made more errors than non-fluent aphasic subjects. Milberg & Blumstein (1981) suggest that it may be the actual decision stage with which fluent aphasic subjects have difficulty. It should be noted that the overall patterns of results found for the fluent aphasics as a group were not consistently replicated in individual fluent aphasic subjects' patterns, reflecting a greater degree of variability for this group than was shown by either of the other two groups. Any conclusions drawn concerning the fluent aphasic patients must therefore be considered with caution.

The present results have implications for the interpretation of previous studies about the semantic and phonological processing of aphasic subjects. In the rhyme judgement task, the two aphasic groups performed similarly. They also showed the same facilitation effects as the normal subjects, although their processing was again slower, and less accurate for "no" responses. Differences between aphasics and controls were more noticeable in the lexical decision task, where lexical access was required. Aphasic subjects were able to judge whether or not two items rhymed, despite impairments in the on-line facilitation of rhyming words. On the face of it, this may seem contradictory to conclusions drawn in other studies that fluent aphasic subjects have greater difficulty with metalinguistic tasks than priming tasks (e.g. Milberg & Blumstein, 1981). The fact is that both lexical decision tasks and relatedness judgement tasks involve a metalinguistic decision. When the decision involves processing at the lexical level, fluent aphasic subjects appear to have more difficulty than either normal subjects or non-fluent aphasic subjects, as demonstrated by their higher error rates and reaction times in lexical decision tasks (Milberg & Blumstein, 1981; the present experiment), and their greater difficulty with semantic judgements (Blumstein et al., 1982). When the decision does not require processing at the lexical level, as in the rhyme judgement task in the current experiment, fluent aphasic subjects show no more difficulty than non-fluent aphasic subjects.

This hypothesized deficit in making metalinguistic decisions at the lexical level appears not to interfere with semantic priming effects (as in Milberg & Blumstein, 1981 and Blumstein et al., 1982), which suggests that semantic lexical structure is preserved in fluent aphasics, despite difficulty accessing the semantic lexicon. However, it does appear to interfere to some extent with phonological priming effects (as in the present experiment), suggesting that fluent aphasic subjects may have a deficit in using phonological information to access the lexicon.

The present results are inconsistent with the mediated priming results of Milberg et al. (1988) in several respects. First of all, Milberg et al. (1988a) found that normal subjects showed more priming from words identical to the mediating word than from non-words rhyming with the mediating word, suggesting that the amount of priming is dependent on the phonological distance of the prime from the mediating word. In the present experiment, the normal subjects did not show greater facilitation of lexical decisions with identical primes than with rhyming primes, a finding that is difficult to account for at present. One difference between the two studies is that Milberg et al. (1988) compared identical word primes to rhyming non-word primes, while the present experiment compared identical word to rhyming word primes. The change in lexical status of the prime may have contributed to their finding of a significant identity effect.

The present results are also inconsistent with Milberg et al.'s results with aphasic subjects (1988b). They reported that non-fluent aphasic subjects showed only direct semantic priming, no mediated priming, suggesting a deficit in rhyme priming in these subjects, or an increased sensitivity to phonological distortion. However, in the current experiment, non-fluent aphasic subjects showed rhyme priming results similar to those of normal subjects. Thus, they did not show a rhyme priming deficit per se. The lack of mediated priming is more likely attributable to the interaction of semantic and phonological processing, or to a deficit in semantic processing itself, as Broca's aphasics have been shown to exhibit inconsistent semantic priming effects (Milberg & Blumstein, 1981).

For fluent aphasic subjects, Milberg et al. (1988b) found mediated priming that was as great as the direct semantic priming, suggesting a decreased sensitivity to the phonological distortion of the prime. In the present experiment, then, one would have expected fluent aphasics to show robust rhyme facilitation of lexical decisions. However, although an overall rhyme effect was found, the facilitation was too weak too show up in post-hoc analyses or even with identity primes. One possible reason for the different results found for fluent aphasics is that Milberg et al. eliminated those patients who showed no direct semantic facilitation from further study. It may be that the elimination of these subjects rendered the fluent aphasic group in Milberg et al.'s study less severely impaired than those tested in the current experiment. The caveat mentioned earlier must also be borne in mind, though: the present group results for the fluent aphasic patients must be interpreted with caution. In general, results of the current investigation suggest that non-fluent aphasic subjects have intact phonological connections, but that these connections may be impaired for fluent aphasic subjects.

The results of the current study may be accounted for, at least in part, by several different models of lexical access. Spreading activation theory (Collins & Loftus, 1975) can account for word/word rhyme priming effects by means of spreading activation along links specifying a phonological relationship between words within a lexical network. However, spreading activation theory is not concerned with sub-lexical activation; activation in this model can only spread from one word node to another. Reference to other models is necessary to account for the priming that was found in conditions incorporating non-words.

Morton's (1969) logogen model provides a means by which non-word/word priming can occur. Activation of logogens occurs by increments as they collect matching visual, auditory, or contextual features from an incoming stimulus. Thus, rhyming non-word and word primes partially activate targets to the degree that they share phonological information; subsequently presented targets then reach their activation threshold more quickly. Identity priming, on the other hand, occurs by a temporary lowering of the logogen's threshold (a frequency-of-occurrence effect). Because two different mechanisms are involved, it should not necessarily be expected that identical primes provide more facilitation than rhyming primes, consistent with results in the present experiment. Logogen theory, however, does not explain the presence of lexical status of prime effects, since features of word primes are presumed to have the same effect upon logogens as features of non-word primes. Facilitation of non-word targets is also difficult to explain within this model, because features are only hypothesized as components of word logogens.

In principle, the autonomous search model (Forster, 1976) could account for differences between word and non-word priming. Forster hypothesized that low activation thresholds allow a non-word to activate the lexical entry for a structurally similar word, which could yield non-word/word priming. Rhyme priming between words, on the other hand, could occur by virtue of their membership in the same bin within the phonological access file. However, Forster assumed that bins are organized somewhat like a dictionary, by shared initial phonemes, and therefore his original model would not provide an obvious mechanism for rhyme facilitation.

Like the autonomous search model, cohort theory (Marslen-Wilson & Welsh, 1978) explains phonological priming as the simultaneous activation of items sharing word-initial phonological information. Because the theory emphasizes word-initial phonological relationships, it is difficult to see how the present rhyme priming results could be compatible with cohort theory.

TRACE theory (McClelland & Elman, 1986), on the other hand, allows for the influence of shared phonological information other than word-initial phonemes. TRACE theory stresses the overall goodness of fit between the complete stimulus and a lexical representation. Unlike logogen theory, sub-lexical units, for example features and phonemes, exist in a hierarchical structure separate from lexical entries. According to this model, rhyme priming of word and non-word targets would be the result of the activation of the sub-lexical units shared by two rhyming words. The prime stimulus BAT, for example, would activate the phonemes /b/, /ae/ and /t/, and the subsequent target CAT would be primed because two of its three components (/ae/ and /t/) were already activated. A non-word such as WAT would also activate /ae/ and /t/ and, thus, prime all actual lexical items containing that combination of phonemes.

However, not all of the present results are compatible with this model. TRACE theory states that nodes within the same level, such as the two lexical nodes BAT and CAT, have an inhibitory relationship, such that the activation of BAT would actually inhibit CAT, even while the phonemes /ae/ and /t/ would be activating it. This may account for the reaction time advantage of non-word over word primes on unrelated word targets, but the current findings of greater facilitation provided by rhyming word primes over rhyming non-word primes are inconsistent with this aspect of TRACE theory. McClelland & Elman (1986) acknowledge the need for a separate lexical mechanism (for example, spreading activation between lexical items) in order to explain word/word priming. Although TRACE does not account for all of the present findings, it appears to best capture the rhyme priming results in the current experiment, as well as word-initial phonological priming results of other studies (e.g. Marslen-Wilson & Zwitserlood, 1989).

In summary, the present study strongly supports the existence of rhyme relationships at both lexical and sub-lexical levels in normal subjects. Although word-initial phonological information has been found to play a role in auditory word recognition (Salasoo & Pisoni, 1985; Marslen-Wilson & Zwitserlood, 1989), word endings have also been implicated (Slowiaczek et al., 1987; Milberg et al., 1988a; Burton, in press). The temporal nature of auditory word processing makes it logical to assume that word-initial information has an advantage in lexical access, if only because it is heard before word-final information. However, rhyme relationships have the advantage of providing maximum phonological similarity between different words. Perhaps this is the reason that rhymes hold a traditional place in the learning and use of language. Rubin & Wallace (1989) cite the use of rhyme in oral traditions such as poetry and as a mnemonic device as evidence of its importance, in conjunction with semantic information. Other types of phonological relationships are also possible within the lexical network, such as syllabic similarity (e.g. Jakimik et al., 1985) or shared morphological segments (Emmorey, 1989). Further research is necessary to determine which structural relationships are most relevant during on-going normal language processing.

Additional research is also needed to clarify the inconsistent findings of mediated priming experiments throughout the literature with normal subjects (e.g. Rosson, 1983; Milberg et al., 1988a; Burton, in press) and with aphasic subjects (e.g. Milberg et al., 1988b). Considering the rhyme priming results of Burton (in press) and those of the current study, the absence of mediated priming cannot be attributed to an absence of phonological priming. Rather, it seems that lexical activation is not always strong enough to spread from a phonological to a semantic network. In aphasia, it may be that it is this link between networks that is disrupted, as opposed to phonological or semantic processing per se. Further mediated priming studies are needed to clarify the respective and interactive roles of semantic and phonological information in normal subjects, and the disruption of these processes in aphasic populations.

The differences shown between the two aphasic groups in the present experiment suggest that phonological processing is more impaired in fluent aphasia than in non-fluent aphasia (cf. Blumstein, 1988). Phonological processing appears to be largely preserved in non-fluent aphasic subjects, although not as efficient as it is in normal subjects. Although fluent aphasic subjects are able to access sub-lexical phonological representations, as demonstrated by their ability to judge rhyming relationships, they appear to have difficulty using phonological information to access lexical representations. Such differences may be important in interpreting receptive language deficits and in choosing therapeutic techniques for aphasic patients.

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Appendix A: Prime-Target Stimulus Sets
(note: target for each set is same as ID prime)

PRIME CONDITIONS FOR WORD TARGETS

ID	WR	NWR	WNR	NWNR	FIL
BOOK	LOOK	ZOOK	RAISE	LEETHE	SOUP
FULL	PULL	ZULL	HOME	PUZZ	FATH
VOICE	CHOICE	LOICE	LIKE	GEN	MAZZ
GET	LET	KET	TUBE	BIM	TODGE
SIT	HIT	VIT	SHOOT	POOK	REEZE
NIGHT	FIGHT	PIGHT	BAG	SULL	KIFF
SHOP	TOP	DOP	JOB	MAPE	FUB
WILL	BILL	LILL	NOSE	REAG	BOVE
COOL	POOL	MOOL	SUIT	HUCK	PIB
WIN	SIN	NIN	LEG	MEP	CHEED
BOAT	COAT	SOAT	DEATH	SAWN	POIL
RACE	FACE	NACE	FOOD	JUM	NUG
LOCK	ROCK	VOCK	MISS	SATHE	BAL
TEACH	REACH	GEACH	NICE	FOSH	BAV
CUT	SHUT	LUT	FAITH	BAUSE	SARE
NECK	CHECK	MECK	TIME	TASH	SEB
MEAN	LEAN	THEAN	PUSH	DEV	TOOP
SHAKE	LAKE	PAKE	WATCH	ROFF	TUSS
SAVE	WAVE	BAVE	CUP	GINE	HOUT
WRONG	LONG	NONG	LEAVE	ZALE	JUFF

PRIME CONDITIONS FOR NON-WORD TARGETS

ID	WR	NWR	WNR	NWNR	FIL
CHOT	HOT	MOT	ROOM	YOLE	KID
KIDE	RIDE	FIDE	BIG	FAM	SHOUT
KALL	HALL	CHALL	BAD	SITCH	FOLK
SHATE	GATE	TATE	TEAM	LOKE	KEEP
NING	KING	SHING	TOWN	MEJ	CATCH
DOAN	BONE	WONE	ROOF	TEM	RUSH
FIV	LIVE	TIV	YOUNG	LADGE	LOOSE
BAME	NAME	VAME	LAUGH	DOOTH	FEED
FIP	SHIP	BIP	HEAR	PUD	DOOR
JEAL	DEAL	BEAL	MOVE	DIZ	CODE
ZICK	THICK	JICK	JUDGE	MISH	CARE
NASS	PASS	RASS	HOPE	BAFE	HANG
KILE	MILE	JILE	MOUTH	SEAF	HOUSE
SAR	FAR	NAR	MAIN	WAT	BED
CHUN	RUN	LUN	JOIN	ROG	TYPE
DAGE	PAGE	MAGE	FOOT	LOM	SEEK
PUTCH	MUCH	RUTCH	RISE	LOCE	GOOD
KEAT	SEAT	DEAT	LOVE	SIJ	LOSS
ZACK	BACK	DACK	TELL	LAN	MOON
HIFE	LIFE	TIFE	NOD	FOATH	CHOOSE

Appendix B: Error Rates of Control Subjects before Elimination of High Error Items

	LEXICAL DECISION		RHYME JUDGEMENT	
	WORDS	NONWORDS	WORDS	NONWORDS
CS-1	0.8%	15.0%	0.0%	0.0%
CS-2	6.7%	7.5%	5.8%	1.7%
CS-3	0.8%	28.3% •	1.7%	0.0%
CS-4	1.7%	0.0%	0.8%	0.0%
CS-5	0.0%	12.5%	3.3%	3.3%
CS-6	7.5%	43.3% •	1.7%	1.7%
CS-7	2.5%	0.0%	1.7%	1.7%
CS-8	0.8%	8.3%	1.7%	1.7%
CS-9	13.3%	20.0%	3.3%	1.7%
CS-10	2.5%	7.5%	0.0%	0.0%
CS-11	4.2%	6.7%	2.5%	4.2%
CS-12	3.3%	4.2%	3.3%	1.7%
MEAN	3.7%	12.8%	2.2%	1.5%

Appendix C: Target Error Rates in the Lexical Decision Task

WORD TARGETS

TARGET	PERCENT
BOOK	2.0%
FULL	16.0%
VOICE	0.0%
GET	18.0%
SIT	6.0%
NIGHT	0.0%
SHOP	0.0%
WILL	0.0%
COOL	0.0%
WIN	4.0%
BOAT	0.0%
RACE	0.0%
LOCK	4.0%
TEACH	2.0%
CUT	0.0%
NECK	8.0%
MEAN	0.0%
SHAKE	2.0%
SAVE	8.0%
WRONG	4.0%

NON-WORD TARGETS

TARGET	PERCENT
CHOT	16.0%
KIDE	38.0% •
RALL	16.0%
SHATE	8.0%
NING	0.0%
DOAN	0.0%
FIV	6.0%
BAME	2.0%
FIP	4.0%
JEAL	18.0%
ZICK	0.0%
NASS	2.0%
KILE	16.0%
SAR	10.0%
CHUN	8.0%
DAGE	0.0%
PUTCH	8.0%
KEAT	0.0%
ZACK	4.0%
HIFE	6.0%

Appendix D: Prime Error Rates in the Lexical Decision Post-Test

WORD PRIMES

TOP	30%	WATCH	0%	NOSE	0%	MUCH	0%
LIFE	20%	YOUNG	0%	LAKE	30%	HOPE	0%
FOOT	0%	NICE	0%	DEATH	0%	HOME	0%
MILE	0%	JOB	0%	MISS	0%	MOON	0%
SHIP	0%	HANG	10%	RIDE	0%	CHECK	10%
LOSS	20%	PULL	30%	TYPE	0%	SEAT	0%
FIGHT	20%	LIKE	10%	PASS	0%	LEAN	0%
WAVE	0%	TUBE	0%	SHOUT	0%	LAUGH	10%
NOD	10%	LET	10%	COAT	0%	MAIN	10%
DOOR	0%	RUN	0%	BAG	10%	KEEP	10%
GATE	10%	JUDGE	0%	HOT	0%	THICK	20%
RUSH	0%	DEAL	20%	FAITH	20%	TOWN	0%
TELL	10%	RACE	0%	RAISE	10%	BACK	0%
TEAM	0%	SHUT	0%	LOOSE	0%	GOOD	0%
ROCK	10%	NAME	0%	HALL	0%	BILL	0%
CATCH	0%	KING	0%	TIME	0%	PUSH	0%
ROOM	0%	HIT	10%	SIN	0%	POOL	10%
BONE	20%	KID	0%	SUIT	0%	BAD	10%
JOIN	0%	ROOF	20%	FOOD	10%	CHOOSE	0%
BIG	0%	LONG	10%	RISE	10%	REACH	10%
MOUTH	0%	HOUSE	10%	HEAR	0%	FOLK	0%
LOVE	0%	LEG	0%	FAR	0%	CUP	0%
LEAVE	0%	CARE	0%	MOVE	0%	SEEK	10%
CODE	0%	PAGE	20%	BED	0%	FEED	0%
SHOOT	0%	CHOICE	0%	LIVE	0%	LOOK	10%

NON-WORD PRIMES

TOOP	10%	DIZ	0%	ZOOK	0%	DEAT	10%
DEV	20%	FAM	0%	PIGHT	10%	SITCH	105
SEACH	10%	MOOL	0%	MECK	10%	JILE	0%
BAL	40%	VAME	0%	RUTCH	0%	ROFF	10%
TIFE	0%	FOATH	20%	NIN	0%	NUG	0%
TASH	10%	BAVE	10%	TODGE	10%	WAT	0%
SULL	40%	DOP	0%	LOICE	0%	PUD	10%
BIF	0%	SOUD	0%	LUN	10%	CHALL	0%
KET	40%	SEB	10%	RUZZ	20%	LUT	0%
KIFF	10%	LEETHE	20%	DACK	0%	SIJ	0%
BOVE	0%	BEAL	30%	MEJ	0%	MAJE	0%
WONE	0%	MAZZ	0%	MEP	30%	FOSH	0%
REEZE	10%	NONG	10%	HUCK	40%	JUFF	0%
MOT	0%	YOLE	10%	GEN	10%	THEAN	20%
FUB	0%	TATE	10%	NACE	10%	SATHE	90% •
TIV	0%	DOOTH	0%	LOKE	10%	BAV	10%
CHEED	0%	MAPE	0%	ZULL	10%	LADGE	20%
LOCE	20%	NAR	0%	BAUSE	30%	POIL	30%
JICK	10%	GINE	0%	RASS	10%	BIM	0%
ROG	90% •	VIT	0%	LILL	10%	LOM	0%
VOCK	10%	SOAT	0%	PAKE	40%	SEAF	0%
HOUT	10%	PIB	0%	TUSS	10%	SALE	0%
LAN	20%	FIDE	10%	SHING	0%	SARE	0%
TEM	0%	MISH	10%	SAWN	10%	KATH	70% •
KEAG	30%	POOK	10%	JUM	0%	BAFE	10%