THE INFLUENCE OF NEIGHBORHOOD DENSITY ON PHONETIC CATEGORIZATION IN APHASIA

Jeffrey P. Boyczuk
School of Communication Sciences
and Disorders
McGill University, Montreal
July, 1997

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

0-612-37099-2

ABSTRACT

The present study was designed to examine the contribution of lexically-based sources of information to acoustic-phonetic processing in fluent and nonfluent aphasic subjects, and age-matched normals. To this end, two phonetic identification experiments were conducted which required subjects to label syllable-initial bilabial stop consonants as either /b/ or /p/. Factors that were controlled included the lexical status (word/nonword) and neighborhood density values corresponding to the two possible syllable interpretations in each set of stimuli. Findings indicated that all subject groups were influenced by both lexical status and neighborhood density in making phonetic categorizations. Although the overall results were inconsistent with the theory that nonfluent aphasics may utilize heuristic strategies in language processing more than fluent aphasics or normals, neighborhood influences seemed to be stronger for both groups of aphasics relative to control subjects. Findings regarding the time course of lexical and neighborhood effects suggested that these influences were co-occurring in phonetic identification. Results are discussed with respect to models of word recognition and theories of acoustic-phonetic perception and lexical access in normal and aphasic populations.

RÉSUMÉ

Cette étude visait à analyser le rôle que jouent les sources d'information lexicales dans le traitement acoustique et phonétique des sujets atteints d'aphasie fluente et non fluente et des sujets témoins du même âge. À cette fin, deux expériences d'identification phonétique ont été réalisées, où les sujets devaient étiqueter comme /b/ ou /p/ des consonnes occlusives bilabiales initiales. Les facteurs contrôlés comprenaient la catégorie lexicale (mot/non-mot) et les valeurs de densité voisine correspondant aux deux interprétations pouvant être données des syllabes dans chaque ensemble de stimuli. Les résultats démontrent que les catégorisations phonétiques ont été influencées tant par la catégorie lexicale que par les valeurs de densité voisine, dans tous les groupes de sujets. Même si les résultats généraux contredisent la théorie selon laquelle les sujets souffrant d'aphasie non fluente recourent parfois plus à des stratégies heuristiques de traitement linguistique que les sujets atteints d'aphasie fluente ou les sujets normaux, l'effet des valeurs de densité voisine semble plus marqué dans les deux groupes de sujets aphasiques que dans le groupe de sujets témoins. Pour ce qui est de l'évolution chronologique de l'effet lexical et de l'effet de voisinage, les résultats semblent indiquer que ces facteurs ont simultanément influencé l'identification phonétique. Les résultats sont examinés à la lumière des modèles de reconnaissance de mots et des théories de perception acoustique et phonétique et d'accès lexical dans les populations normales et aphasiques.

ACKNOWLEDGEMENTS

My sincerest thanks go to Shari Baum, my supervisor, whose wealth of knowledge, guidance, and unfailing support have been instrumental in the completion of this project.

Additional thanks go to Paul Luce and Michael Vitevitch for providing neighborhood density values, Jeanne Gordon for commenting on the original draft of the Introduction, and to Anita Shuper for help in recruiting and running subjects. I am also grateful for the patience and cooperation of all the subjects who participated in this study.

This research was supported, in part, by grants from the Fonds FCAR du Québec and the Medical Research Council of Canada.

Table of Contents

List of Tables

List of Figures

Introduction

It is a truism that conversational speech is a continuous stream of acoustic elements that must, at some point, be broken down by a listener into its constituent parts -- words -- in order to derive meaning. A fundamental goal of speech perception research has been the identification of perceptual units in the speech signal that must be isolated by listeners in order for word recognition to take place. The prevalent view among theorists is that the minimum semantically contrastive sound units of a given language -- phonemes -- must be identified at some stage in normal speech processing (Elman & McClelland, 1984; Forster, 1976; Liberman, Cooper, Shankweiler, & Studdert-Kennedy, 1967; Marslen-Wilson & Welsh, 1978; McClelland & Elman, 1986). Assuming this is the case, models of word recognition must address the formidable problem of how these acoustic segments are perceived, compiled and mapped onto a single word from among the 75 000 or more members that are estimated to comprise the adult lexicon (Oldfield, 1966). Research along many fronts has supported the notion that word recognition is achieved through the interaction of low-level perceptual information extracted from the speech signal and high-level linguistic sources such as lexical, syntactic and semantic constraints that are imposed by conversational context (Blank & Foss, 1978; Luce, Pisoni, & Goldinger, 1990; Marslen-Wilson, 1975; Marslen-Wilson & Zwitserlood, 1989; Samuel, 1986). Still, the precise nature of these interactions remains unclear. It has been suggested that phonetic categorization is an autonomous stage of speech processing and that any high-level linguistic influences, such as lexical status (word or nonword), may only bias the output of this stage (Fox, 1984). An alternative view is that high-level linguistic sources interact directly with phonetic perceptual processes, their relative contribution dependent upon the degree of ambiguity of the acoustic-phonetic signal (Ganong, 1980). This latter view is consistent with research suggesting that lexical effects in phonetic categorization are not matters of course, but emerge when the acoustic signal is unnatural or contains conflicting phonetic cues (Burton, Baum, & Blumstein, 1989). Such suggestions have implications for aphasic patients who have demonstrated impairments in identifying and discriminating phonemes. If top-down processing in phonetic categorization operates as a type of compensatory strategy in the case of incomplete or disrupted acoustic information, perhaps it may also compensate for deficits in acoustic-phonetic perception. In any case, questions remain over what conditions are necessary for high-level sources to contribute to perceptual decoding of the speech signal and at what processing point these sources act to influence the identification of phonemes in both normals and brain-damaged patients. With a general acceptance that phonetic patterns are somehow reliably extracted from the speech signal by listeners, many researchers have focused on the more global structure of word recognition, and the nature of the interactions among the processes involved in moving from an acoustic signal to accessing lexical members. Several such theories will be reviewed in the following section.

Models of Word Recognition

An early and influential model of word recognition was Logogen Theory (Morton, 1969, 1979). This model proposes that word recognition is achieved through a network of "logogens" that represent individual words or morphemes. Each logogen receives sensory input derived from an acoustic signal and contextual input (such as syntactic and semantic information) from other logogens that have been activated by the preceding context. A given logogen compares all sources of input to a body of internal information about the morpheme or lexical member it represents. Matching features, whether from acoustic-phonetic, lexical, syntactic or semantic sources, are tabulated. Once the logogen's feature counter reaches a predesignated threshold, a word is recognized. This model has a competition view of lexical access, with many logogens that share features with the target stimulus receiving input simultaneously, but the one reaching threshold first emerging as the recognized word.

It is notable that logogen theory does not define a discrete stage of phonetic identification. In fact, since word recognition is completely dependent upon reaching a numerical threshold of matching features, it is not important whether input that pushes a logogen over its threshold is from sensory or contextual information (Jusczyk, 1986). Studies demonstrating a phonemic restoration effect (e.g. Samuel, 1981; Warren, 1970) have supported such an interaction of bottom-up and top-down processing. For example, Warren (1970) replaced a phoneme from a particular word in a spoken sentence with a cough. Subjects who listened to these sentences had trouble determining where the cough occurred, suggesting that contextual information had helped achieve word recognition despite the absence of a complete phonetic representation. Such a finding is consistent with the processing structure proposed by Logogen theory. Logogen theory can also account for results of gating studies (Grosjean, 1980; Salasoo & Pisoni, 1982) which have shown that words presented in sentence contexts may be identified with far less acoustic information than those appearing in isolation.

A descendent of the logogen model that also stresses an interactive approach to word recognition is Cohort Theory (Marslen-Wilson & Welsh, 1978; Marslen-Wilson & Tyler, 1980, 1981). This model views the first stage of auditory word recognition as the activation of a group of words, a cohort, that share the same initial acoustic-phonetic information as the target word. For example if the sentence "I ate a p-. . .," was spoken, "paper," "peach," "pot," "plum," "pear," "pencil," and many other words beginning with the phoneme [p] would be activated. Word candidates from this initially activated cohort would be eliminated in response to contextual information provided by the sentence (for example, "paper," "pot," "pencil" would be eliminated as inedible) and/or continuing phonetic information (i.e. if the next phoneme was [l], "peach" and "pear" would be eliminated from the above cohort, leaving "plum"). Through the interactive effects of acoustic-phonetic and contextual information, a cohort is reduced to a solitary member, resulting in word recognition. From this example it is clear that within this theory, phonetic information at the beginning of words is vital in establishing an initial cohort of lexical candidates from which a word will ultimately be selected. Several studies have supported the importance of word-initial information in lexical access (Cole, 1973; Cole & Jakimik, 1978; Nooteboom, 1981).

Studies utilizing the shadowing paradigm (Marslen-Wilson, 1975, 1985; Marslen-Wilson & Welsh, 1978) have been cited in support of cohort theory. In an early study, Marslen-Wilson (1975) asked subjects to repeat recorded passages as quickly as possible as they were heard. Certain words within the recorded passage were intentionally mispronounced (e.g. "compsiny" instead of "company"). Results showed that some subjects were able to repeat spoken passages almost in synchrony with what they were hearing. As well, it was found that these "close shadowers" would spontaneously correct words in the passages that they had been hearing with no break in their flow of repetition. Apparently, contextual influences allowed subjects to access lexical candidates before receiving complete phonetic information, resulting, in some cases, in repetition that was almost synchronous with the spoken passage being heard. It was further noted that as syntactic, semantic and lexical constraints upon mispronounced words were increased (making sentences more predictable), shadowing latencies decreased and the percentage of error corrections of phonetically altered words increased (Marslen-Wilson, 1985). These findings suggested that, under the conditions of speeded response, subjects were not able to analyze the incoming speech signal without being influenced by top-down, contextual sources of information.

While the initial versions of cohort theory (Marslen-Wilson & Welsh, 1978; Marslen-Wilson & Tyler, 1980, 1981) proposed a phonemic level of perception in the process of moving from the speech signal to accessing lexical candidates, more recent versions have suggested that featural information is directly mapped onto lexical representations, with no mediating stage of phonetic identification (Marslen-Wilson & Warren, 1994; Marslen-Wilson, Moss, & van Halen, 1996). This revision was based on evidence demonstrating that words which were edited to contain conflicting featural information resulted in increased reaction times (RTs) for subjects on lexical decision tasks for words but not for nonwords. This suggested that listeners were not integrating low-level, featural information at a pre-lexical level. If phonetic identification is a prerequisite to lexical access, conflicting featural cues would be expected to slow RTs to lexical decisions for nonwords as well as words. Since the results showed only an effect of featural mismatches on word lexical decisions, it was proposed that the integration of featural information first occurs at a lexical level, with no intervening stage of phonetic identification.

Another model of word recognition that also considers contextual information as a source of input in processing the speech signal is TRACE Theory (Elman & McClelland, 1986; McClelland & Elman, 1986). This theory is based on a neural network of nodes which bear some resemblance to Morton's logogens. A primary difference between the two models is that Elman and McClelland's system proposes intricate connections between nodes, whereas Morton's logogens are considered to be more independent processing units. TRACE theory posits three levels of nodes that are bidirectionally connected. The first level corresponds to phonetic features, the second level represents phonemes, and word nodes comprise the highest level. The speech signal first excites nodes at the level of features which, upon reaching their thresholds, excite the phoneme nodes which are made up of those particular features. At the same time, competing feature nodes at the same level are inhibited by the activated feature nodes. In turn, activated phoneme nodes excite word nodes that are comprised of these phonemes. The bidirectionality of the model means that as soon as a node reaches threshold, it not only excites nodes at a higher level, but also provides feedback to nodes at a lower level. For example, a node that corresponds to voicing may be driven to threshold by an auditory signal and, combined with other activated nodes at the featural level, may drive the activation level of a node representing [b] to threshold. This activated [b] node, in turn, not only excites word nodes that contain its phoneme, but also feeds back to the voicing node and other feature nodes that originally raised its own activation level. The TRACE model is the epitome of the interactive view of speech perception, with word-level information contributing to the low-level feature extraction processes involved in decoding the speech signal.

A recently proposed theory of word recognition that deals primarily with the issue of competition among lexical candidates is the Neighborhood-Activation Model (Luce et al., 1990). This model assumes that a given auditory stimulus activates a group of similar acoustic-phonetic patterns in memory -- its neighbors -- and that the activation levels of these patterns are a direct function of their phonetic similarity to the auditory stimulus. For example, the neighborhood for "pace" would be comprised of such words as "page", "face", "pain", "mace", "push", etc. The primary assumption of the model is that the denser the neighborhood for a given word, the longer it will take to be recognized. The probability of recognizing a word is based on the following rule developed by Luce (1986):

$$p(\text{ID}) = \frac{p(\text{stimulus word}) \times \text{freq}_s}{p(\text{stimulus word}) \times \text{freq}_s + \sum_{j=1}^{n}\{p(\text{neighbor}_j) \times \text{freq}_j\}}$$

The *neighborhood-probability rule* states that the probability of correct identification of the stimulus word is equal to the frequency-weighted probability of the stimulus word (p(stimulus word) x freq_s) divided by the frequency-weighted probability of the stimulus word plus the sum of the frequency-weighted probabilities of

> the neighbors ($\sum_{j=1}^{n}\{p(\text{neighbor}_j) \times \text{freq}_j\}$). In general, this rule states the probability of choosing the stimulus word from among its neighbors. (Luce et al., 1990, p. 125)

It should be noted that the neighborhood density value is dependent not only upon the number of neighbors a word has, but also the sum of their relative frequencies of occurrence. Somewhat similar to Logogen theory, the neighborhood activation model proposes that a series of decision units receive input from bottom-up phonetic sources and top-down lexical and syntactic sources. Ultimately, output from this system of units allows the listener to select a particular word, and all sources of information corresponding to that word (phonetic, syntactic, semantic etc.) become available to working memory.

While all of the models discussed above include some form of interaction between perceptual and high-level linguistic components, the precise nature of these interactions is not always explicitly defined. Many researchers have attempted to more acutely investigate the contribution of high-level sources of linguistic information to low-level perceptual decoding of the speech signal. A particularly fruitful line of inquiry has been the investigation of lexical influences on the identification of phonemes.

Phonetic Categorization and the Lexical Effect

This issue was first addressed by Ganong (1980) who examined whether the lexical status (word or nonword) of a syllable would affect the perception of a phoneme contained within it. Ganong created sets of seven-step acoustic continua varying in voice onset time (VOT) between two syllable-initial stop consonants. The two endpoints of each continuum were considered unambiguous stimuli since their syllable-initial consonants were consistently categorized across subjects as one or another member of a voiced/voiceless cognate pair. Five "steps" were created between the two endpoints by systematically varying the VOT. The critical factor in this study was the lexical status of the endpoint stimuli. All continua were constructed so that the lexical status of the endpoints differed. For example, the /d/ - /t/ continua included a dash-tash continuum (in which only the voiced endpoint forms a real word) and a dask-task continuum (in which only the voiceless endpoint forms a real word). Results of a phonetic identification task showed that subjects tended to make more phonetic categorizations that were consistent with the word ends of the continua. That is, more /d/ categorizations were made for the dash-tash continuum and more /t/ categorizations were made for the dask-task continuum. This "lexical effect" proved to be greater in the region where auditory information was most ambiguous -- near the phoneme boundary -- than at the ends of the continua, although a small effect was apparent at the endpoints as well (Ganong, 1980).

While this demonstration of a lexical effect showed that there may be higher level linguistic influences that bias phonetic identification, it did not conclusively determine whether such influences were interactive with the phonetic categorization process or were, in fact, post-perceptual biasing processes that acted on the output of a phonetic categorization stage (Fox, 1984). Ganong (1980) distinguished between two possible models of phonetic perception: the categorical model and the criterion-shift model. The categorical model views the lexical effect as the product of a correction process that operates on the output of a phonetic decision stage. Such a model predicts that the lexical effect would be equally distributed across an acoustic continuum, since it is operating only on the output of the phonetic categorization process. The criterion-shift model, on the other hand, proposes that the actual criterion for making a phonetic categorization is, in part, dependent on the lexical status of the stimuli. In other words, lexical status is interactive with phonetic categorization. In such a case, the weight of lexical information in making a phonetic categorization is dependent upon the confidence of an acoustic-phonetic decision process operating only on auditory input. If an auditory signal is sufficiently unambiguous for such perceptual processes to make a phonetic decision based on acoustic information alone, lexical influences may not be necessary. Ganong suggested that the results of his study, which showed a greater lexical effect at the phoneme boundary than at the endpoints of the continuum, support the criterion-shift view, since such a model predicts that the phoneme identification process will place more weight on the lexical status of a phonetically ambiguous stimulus in making a phonetic categorization.

In a follow-up study, Fox (1984) questioned this interactive view of phonetic perception and noted that Ganong's interpretations were based solely on identification functions and interpolated phoneme boundaries while ignoring the actual time course of the lexical influence. To address this issue, Fox conducted a phonetic identification study exploring the lexical effect, in which RTs of subjects were measured and partitioned into fast (RT $\leq$ 500ms), medium (500ms < RT $\leq$ 800ms), and slow (RT > 800ms) ranges. While the results of this study also showed a much greater lexical effect for acoustically ambiguous stimuli, interestingly, the lexical effect was not present in the fast RT range. Fox suggested that this result provided evidence that listeners initially make phonetic categorizations based on acoustic information alone, and that the lexical influences only emerge when given enough time to operate on the output of this initial phonetic decision stage. This limiting of the lexical effect to slow and intermediate ranges has been replicated in studies with similar methodologies that have partitioned responses into such RT ranges (Burton et al., 1989; Miller & Dexter, 1988; Pitt & Samuel, 1993).

As the body of research examining lexical influences in phonetic identification has grown, the emergence of the lexical effect has become increasingly variable. Although it makes intuitive sense that lexical effects on phonetic perception should be equally strong regardless of the phonetic contrasts used (i.e. place, manner or voicing), this has not proven to be the case (Pitt & Samuel, 1993).

One possible source of variability in these studies that has been proposed is the neighborhood density of the endpoint stimuli (Newman, Sawusch, & Luce, in press; Sawusch, Newman, & Luce, 1993). In terms of phonetic categorization, the neighborhood-activation model predicts that if everything else is held constant (i.e. the lexical status of the endpoints and the structure of the stimuli), the endpoint with the denser neighborhood will attract more responses in the ambiguous stimuli region -- a result that is parallel to the lexical effect which favours the word end in a word-nonword continuum. To test for this influence, Sawusch et al. (1993) constructed voicing continua utilizing only nonword endpoints that differed in neighborhood density. For example, one pair of continua included a series ranging between the nonwords beyth and peyth while another ranged between beysh and peysh. In the first case, beyth had a greater neighborhood density and in the second case, peysh had the greater density. Results showed that subjects demonstrated a small effect of neighborhood density, tending to categorize ambiguous stimuli in favour of the end with the greater density. The findings of this study call into question the results of previous research demonstrating lexical effects in phonetic categorization in which neighborhood density was not controlled. If neighborhood density is an important factor in these types of tasks, it is important to re-examine previous stimuli that have produced lexical effects for possible biases of neighborhood density. As with lexical influences, it is also important to determine the stage in speech processing at which neighborhood density influences phonetic perception. Sawusch et al. (1993) noted that neighborhood density effects seemed to be the greatest in intermediate reaction times. This led them to question whether research by Fox (1984) that had found a lexical effect in slow and intermediate reaction times of subjects may actually have been masking a density effect. In a follow-up study, Newman, Sawusch and Luce (1994) constructed word-nonword voice onset time (VOT) continua in which neighborhood effects were neutralized by ensuring that the voiceless endpoints in each continua had equally greater density values than voiced endpoints. The results demonstrated a lexical effect only in slow reaction times, suggesting that previous findings of shifts in phonetic boundaries in intermediate reaction times may, indeed, have actually been due to effects of neighborhood density. These findings also provide further support for models of phonetic identification that posit that higher-level influences emerge only post-perceptually.

Another potential source of variability in eliciting the lexical effect may be differing methodological procedures employed by researchers (Pitt & Samuel, 1993). A factor that has been shown to play a major role in the pattern of results is whether experimental tasks have required the categorization of token-initial or token-final phonemes. In the latter case, it may be assumed that listeners always receive lexical information before responding. In fact, studies requiring final phoneme identification have shown the opposite pattern from those requiring stimulus-initial phoneme identification, with the greatest lexical effect emerging in the fast RT range, a similar size effect in the intermediate RT range, and no effect in the slow range (McQueen, 1991; Pitt & Samuel, 1993). These differences might be explained in terms of the time course of activation and deactivation of lexical entries. If subjects are required to categorize a phoneme that is in word-final position, they will be forced to process all the phonetic information in the carrier word. Hence, it is likely that the carrier word is activated before or concurrent with the perceptual realization of the final phoneme (cf. Grosjean, 1980, 1985; Salasoo & Pisoni, 1982). This would account for an effect in the fast reaction time range. Weaker or absent effects in medium and slow ranges may be due to the rapid fading (or return to resting level) of the lexical carrier's activation.

It has also been suggested that the unnatural acoustic structure of test stimuli used in previous research may have been a factor in producing lexical effects (Burton et al., 1989). Specifically, Burton et al. (1989) noted that, in the place-of-articulation continua utilized by Fox (1984), the stop consonants were constructed based solely on formant transitions, with no bursts. This does not reflect the abundance of cues that are available in natural speech. It has been shown that stop consonants synthesized as bursts plus transitions result in better identification of place-of-articulation than those synthesized as transitions alone (Blumstein & Stevens, 1980; Stevens & Blumstein, 1978). Similarly, voicing continua that have produced lexical effects in several studies (Connine, 1987; Ganong, 1980; Miller & Dexter, 1988) have utilized stimuli that varied only along the dimension of VOT. However, it has been noted that amplitude of both burst and aspiration provide important cues to voicing in stop consonants in natural speech (Repp, 1984) and that other spectral properties of the burst co-vary with VOT (Lisker & Abramson, 1964; Pickett, 1980). To investigate the extent to which these acoustic variations may contribute to the lexical effect, Burton et al. (1989) constructed VOT continua with stimuli that more closely approximated the acoustic parameters in natural speech. More specifically, the authors systematically varied the amplitude of the burst and aspiration in tandem with variations in VOT. Results showed no evidence of a lexical effect in any reaction time range. The authors concluded that when test continua utilize stimuli that closely approximate natural speech, the lexical effect disappears. Thus, the lexical effect that emerged in previous phonetic categorization studies may have been the product of stimuli that contained conflicting acoustic cues and were inherently unnatural.

These results suggest some interesting possibilities for impaired acoustic-phonetic perception that is commonly seen in aphasia. If a lexical effect emerges in listening situations where a confident phonetic decision cannot be made (as suggested by Burton et al., 1989), perhaps listeners who have inherent deficits in categorizing phonetic segments may also be aided by such compensatory, top-down processing. An examination of the relationship between phonetic perception and auditory comprehension deficits in aphasia may shed some light on this possibility.

Phonetic Perception in Aphasia

Research has provided evidence for disruptions along several different dimensions of acoustic-phonetic perception in aphasia. While identification of vowel contrasts seems to be largely unimpaired across aphasic types (Gow & Caplan, 1996), consonantal stimuli have brought to light perceptual deficits corresponding to different phonetic features of speech. The two features that have attracted the most attention in perceptual research with aphasic patients are voicing and place-of-articulation. Although it has been noted that perception of both types of features may be impaired in aphasia, place contrasts seem to consistently create greater difficulties for subjects (Blumstein, Baker, & Goodglass, 1977; Miceli, Caltagirone, Gainotti, & Payer-Rigo, 1978). Yeni-Komshian & Lafontaine (1983) note the differences in featural information that must be perceived in the two contrast types. While discrimination of voicing in stop consonants is based on temporal information (voice-onset time) that is found mainly in the low-frequency range of the speech signal, the acoustic cues for place of articulation are spectral in nature and are found at higher frequencies. Normals have also consistently shown more confusion in processing place as opposed to voice contrasts (Wang & Bilger, 1973).

While acoustic-phonetic perceptual impairments have not consistently proven to distinguish clinical aphasia types, it has been noted that mixed anterior aphasics have evidenced the most severe phonetic perceptual deficits, followed by Wernicke's aphasics and then Broca's aphasics (Gow & Caplan, 1996). Despite this, the trend in acoustic-phonetic research in aphasia has not tried to link perceptual deficits to aphasia type as much as it has attempted to explore the relationship between these impairments and auditory comprehension (Blumstein et al., 1977; Luria, 1947, 1970; Tallal & Newcombe, 1978; Varney, 1984; Yeni-Komshian & Lafontaine, 1983). Perhaps this is a more fitting approach considering that comprehension problems are seen, to some degree, across practically all aphasia types. Indeed, researchers have noted that auditory comprehension serves as a more useful predictor of phonetic perception impairments than do clinical aphasia classifications (Varney, 1984; Yeni-Komshian & Lafontaine, 1983).

Despite this assertion, the results of studies investigating the relationship between acoustic-phonetic deficits and impaired auditory comprehension have been equivocal. Yeni-Komshian and Lafontaine (1983) investigated the ability of aphasic patients to identify and discriminate voicing and place contrasts taken from synthetic speech continua. The authors found that auditory comprehension scores were, "to some extent," predictive of aphasic subjects abilities to perceive these phonetic cues. More specifically, their results showed that accuracy in perceiving these contrasts was higher in a pre-defined "good" comprehension group as compared to a "moderate" comprehension group. However, the authors also noted that the three aphasic subjects who had the highest degree of accuracy on identification and discrimination tests (and even outscored some age-matched normal subjects) did not have correspondingly high language comprehension scores. This dissociation represents the typical pattern of variability amongst aphasic subjects in phonetic categorization studies, indicating there is no straightforward, one-to-one relationship between auditory comprehension and phonetic perception. In fact, several similar studies have failed to find any strong relationship between speech perception ability and auditory comprehension (Basso, Casati, & Vignolo, 1977; Blumstein et al., 1977, Miceli, Gainotti, Caltagirone, & Masullo, 1980).

It has been suggested that one reason why research has failed to demonstrate a systematic relationship between acoustic-phonetic deficits and auditory comprehension is that some aphasics are able to perceive phonological contrasts, but are not able to properly map these phonological patterns to the lexicon (Blumstein, 1991). Two studies by Milberg, Blumstein, and Dworetzky (1988a,b) utilized a lexical decision task with semantically related prime--target word pairs and systematically changed the first phoneme of the prime by one or more phonetic features (e.g. cat-dog, gat-dog, wat-dog). Results for normal subjects (Milberg et al., 1988a) showed that priming (reflected in reaction times of lexical decisions) decreased as a function of phonological distance from the prime (i.e., "gat" primed "dog" better than did "wat"). In a follow-up study (Milberg et al., 1988b), fluent aphasic patients showed equivalent priming in all conditions of phonological distortion, suggesting that these individuals may in essence "overactivate" the lexicon (perhaps producing auditory comprehension deficits), while nonfluent aphasic patients showed priming only in the undistorted (word) condition, suggesting that these patients may be limited in their ability to use acoustic-phonetic information to access the lexicon.

Recent investigations have examined the effects on lexical access of more subtle variations of the acoustic signal within the bounds of a phonetic category. The basis for this type of research is the proposal that phonetic categories contain a central prototype that characterizes a phonetic feature, with less typical exemplars surrounding it. Such a framework has been suggested for VOT categories which provide acoustic cues for the identification of initial stop consonants (Miller, Green, & Reeves, 1986). For instance, Andruski, Blumstein, and Burton (1994) conducted an auditory semantic priming experiment to examine whether subphonetic manipulations in VOT would affect lexical access. Using a lexical decision task, the authors systematically manipulated the VOT of word-initial voiceless stop consonants that resided in prime words. Primes were semantically related to lexical decision targets (e.g. prime: "cat"; target: "dog"). Using an interstimulus interval (ISI) of 50 ms (duration between presentation of the prime and the target word), the authors found that reaction times to targets were significantly slower for primes in which VOT for the voiceless initial consonant was reduced by two-thirds (making the value closer to voiced) as compared to unaltered primes. A phoneme identification task using altered primes was run to ensure that subjects still perceived these phonemes as voiceless. Interestingly, a similar effect did not emerge when an ISI of 250 ms was employed, suggesting that the effects of subphonetic manipulations on lexical access are short-lived in normal processing. A similar study was conducted with aphasic patients by Aydelott-Utman and Blumstein (1995). The authors were interested in whether Broca's aphasics would be sensitive to subphonetic differences in VOT categories. Using a lexical decision task similar to Andruski et al. (1994), results showed that Broca's patients had increased reaction times to altered primes at 50 ms and 250 ms ISIs. Subphonetic effects were even greater when altered primes had a voiced counterpart that resulted in a real word (e.g. altered prime: "pill", counterpart: "bill"). The authors also conducted a discrimination task, requiring subjects to respond "same" or "different" to pairs of stimuli utilized in the lexical decision task. Unaltered primes were the second item in each test pair and altered or unaltered primes were used as the first member of the pair. It was found that Broca's patients responded "same" to both unaltered-unaltered and altered-unaltered pairs but that reaction times were significantly slower for pairs which contained an altered prime. Taken together, the results from these two experiments demonstrate that Broca's aphasics are sensitive to fine acoustic manipulations in the speech signal and suggest that lexical processing deficits that have previously been noted in these patients are not the result of a deficit in their ability to process low-level featural information in the speech signal.

An interesting result that emerged from these two studies was the difference in the duration of the effects of subphonetic manipulations between normals and Broca's aphasics. While normals only showed effects at short ISIs of 50 ms, Broca's aphasics proved to be sensitive to manipulations at both 50 and 250 ms ISIs. A possible explanation for this is that lexical influences were not allowed enough time to bias normal subjects' phonetic processing at 50 ms ISIs, but were able to compensate for the subphonetic alterations when primes were presented at 250 ms intervals. Results showing that Broca's subjects performed the same at both ISIs suggest that such a top-down influence on speech perception processes may be even more delayed in these patients, due to lower initial levels of activation in their lexicon (Blumstein, Milberg, & Shrier, 1982; Milberg & Blumstein, 1981; Milberg, Blumstein, & Dworetzky, 1987, 1988b). These findings raise questions about the nature of top-down processing in aphasic speech perception. Studies with aphasic patients that have provided evidence for top-down processing on acoustic-phonetic perception have been few in number.

A case study by Caplan and Aydelott-Utman (1994) examined the relationship between an acoustic impairment in the discrimination of voicing and lexical access in a Wernicke's aphasic patient, M.L. A voicing discrimination deficit was established through testing which required responses of "same" or "different" to pairs of nonwords that varied only in the voicing feature. Further, two single-word lexical decision tasks were employed to test the hypothesis that M.L.'s recognition of words containing voiced or voiceless stops or fricatives would be impaired relative to words which required the perception of phonetic features other than voicing. A stimuli set of 96 items was constructed, half of which were words and half nonwords. Each stimulus contained at least one stop or fricative consonant, with half of these occurring in stimulus-initial position, and half in stimulus-final position. Further, half of the nonwords were selected so that a change in voicing would result in a word (e.g. "jas" - "jaz") while the other half of the nonwords remained a nonword with a change in voicing (e.g. "vope" - "vobe"). Similarly, half of the word stimuli remained words with a voicing change (e.g. "fan" - "van") while the other half became nonwords with a voicing change (e.g. "soon" - "zoon"). Assuming M.L.'s phonetic impairment would affect her ability to access a proposed phonological input lexicon (Blumstein, 1991; Elman & McClelland, 1984, 1986; Stevens, 1986), Caplan and Aydelott-Utman (1994) predicted that she would show more difficulty identifying words in the lexical decision task whose voicing contrast resulted in nonwords, and in rejecting nonwords whose voicing contrast resulted in words. Results from this task did, in fact, support this prediction. M.L. showed a greater percentage of errors identifying words that became nonwords with a voicing change than words that remained words with a voicing change. Similarly, her performance was notably poorer in rejecting nonwords that became words with a voicing change as compared to rejecting nonwords that remained nonwords with a voicing change.

A phoneme-discrimination task using word pairs that differed in voicing (e.g. pan-ban) and a picture-matching task involving pairs of objects whose names differed only in terms of voicing (e.g. van-fan) were also administered. Results in the phoneme-discrimination task using word stimuli showed that M.L. did not demonstrate any impairment in discriminating words that contained consonants differing in voicing. In the picture-matching task, M.L. scored 29/32, demonstrating strong ability in discriminating between voicing distinctions in spoken words. These results are in stark contrast to M.L.'s poor discrimination of nonword stimuli.

It is notable that M.L.'s impairment in the perception of voicing only affected tasks involving nonwords. This is in agreement with previous research showing higher phonetic discrimination scores for words than for nonwords (Blumstein et al., 1977). The authors note that one possible explanation for this may be feedback from phonological word forms to acoustic-phonetic processing (Ganong, 1980; Elman & McClelland, 1984; Samuel, 1981). In such a case, word stimuli would provide enough phonetic information (beyond a misperceived voicing segment) in order to activate a phonological-lexical entry. This activated lexical entry, containing an intact phonological representation of the word, may feed back to perceptual processes, essentially covering up a deficit in the perception of the acoustic cues that correspond to voicing. Since there are obviously no lexical-phonological forms stored for nonwords, a deficit in the perception of voicing is readily apparent. Because a deficit in discriminating voicing only emerged in the lexical decision task, the authors suggest that such lexical feedback might be task-specific. In any case, the proposal that phonological-lexical forms feedback to perceptual processes may account for the discrepant results between discrimination of word and nonword stimuli in this study.

A more direct investigation of the influence of top-down processes on phonetic perception in aphasia was undertaken by Blumstein, Burton, Baum, Waldstein, and Katz (1994). These researchers examined the role of lexical status in phonetic categorization on a pair of [d] - [t] VOT continua. Stimuli (a subset of those used by Burton et al., 1989) were constructed so that endpoints on the continua were either word-nonword, i.e., "duke" - "tuke", or nonword-word, i.e., "doot" - "toot" (it is recognized that "tuke" is the phonological equivialent of the real word "touque" in Canadian English, but was most likely not familiar to the American subjects who participated in this study). Fluent (Wernicke's and Conduction) aphasics and nonfluent (Broca's) aphasics were required to identify the first sound of the stimulus as either /d/ or /t/. Blumstein et al. (1994) found a large lexical effect for nonfluent aphasics who identified significantly more "d" responses for the "duke"-"tuke" stimuli than the "doot"-"toot" stimuli. Normal controls showed a small lexical effect, whereas fluent aphasics showed none.

The results for nonfluent aphasics are particularly interesting since they show a greater lexical effect than that seen in normal controls in this study. In fact, Burton et al. (1989), who utilized the same continua, found no effect of lexical status in normal subjects. Blumstein et al. (1994) suggested that nonfluent aphasic subjects may utilize a lexical strategy as a means of compensating for impaired phonetic perception. It is also interesting that Wernicke's and Conduction aphasics showed no lexical effect in their categorizations along the [d]-[t] continuum. If the effect seen in Broca's aphasics is due to a compensatory strategy to aid speech perception, it might be expected that Wernicke's aphasics would show an even stronger effect since their deficits in speech perception are typically more severe than those seen in Broca's aphasia. This was not the case. The lack of an effect in the Wernicke's group is explained in terms of an inability to use lexical strategies (Blumstein et al., 1994). Evidence of lexical processing deficits in this group has been shown through their significantly slower reaction times in lexical decision tasks and their poor performance in making semantic-relatedness judgements (Blumstein et al., 1982).

Another approach to examining the role of lexical influences in acoustic-phonetic perception in aphasia may be through the exploitation of neighborhood density. It has been noted that phonological processing deficits may differentially impair fluent and nonfluent aphasic patients' ability to access lexical items (Baker, Blumstein, & Goodglass, 1981; Milberg et al., 1988b). Research has also suggested that nonfluent Broca's aphasics may, in general, be more inclined to utilize heuristic strategies in language processing than Wernicke's aphasics or normal subjects (Blumstein, Milberg, Dworetzky, Rosen, & Gershberg, 1991; Milberg, Blumstein, Katz, Gershberg, & Brown, 1995). Despite these findings, there have been few previous studies that have investigated the possibility that aphasics may similarly employ heuristic strategies in acoustic-phonetic processing (e.g. Blumstein et al., 1994). Searching for a possible neighborhood density effect in phonetic identification provides another means for determining whether different types of aphasics might utilize such strategies to compensate for impairments in low-level perceptual processing.

The objectives of the present study are twofold. First, an attempt will be made to determine if previous demonstrations of the lexical effect in phonetic categorization tasks in both normals and aphasic patients may have been biased by neighborhood density, confirming Sawusch et al.'s (1993) findings for normal subjects (see also Newman et al., in press) and extending the results to aphasic patients. To this end, Experiment 1 will be an effort to replicate the lexical effect with VOT continua in which the word-nonword and nonword-word endpoints are controlled for neighborhood density (as per Luce et al., 1990). Apart from Sawusch et al. (1993) and Newman et al. (in press), there have been few phonetic identification or discrimination studies utilizing acoustic continua that have controlled for the neighborhood density of the endpoints. Second, the use of heuristic strategies in phonetic perception by aphasics will be further investigated by examining effects of neighborhood density alone on phonetic perception. Experiment 2 will once again utilize VOT continua but will have only nonword endpoints that differ in neighborhood density. As noted earlier, use of heuristic strategies by nonfluent Broca's aphasic patients has been suggested by Blumstein et al. (1994) based on data showing a larger lexical effect for Broca's aphasics than normals on a phonetic categorization task. Neighborhood density provides an alternative means of investigating whether lexically-based strategies may be differentially utilized in phoneme perception by normal subjects and by fluent and nonfluent aphasics.

If the lexical effects observed for aphasic patients by Blumstein et al. (1994) were not biased by neighborhood density, then effects of similar magnitude would be expected in Experiment 1, with nonfluent Broca's aphasics showing a greater influence of lexical status than normals and fluent Wernicke's aphasics showing no effect. Similarly, if Broca's aphasics demonstrate a heavier reliance on lexical-heuristic strategies in phonetic categorization in general, the results of Experiment 2 should show a larger effect of neighborhood density for Broca's aphasics than normal subjects and little or no effect for Wernicke's aphasics. This is predicted given that the effect of neighborhood density, while not the "lexical effect" described by Blumstein et al. (1994), is, in fact, dependent upon lexical influences.

If these projected results hold true, several important implications about normal speech perception will emerge. If the lexical effect fails to surface when neighborhood density is controlled in word-nonword continua, then the importance of the lexical status of stimuli may have been overemphasized in past research. Likewise, if nonword-nonword continua show an effect of neighborhood density, it would suggest that the lexical neighborhoods of the endpoints have played a significant role in phonetic categorization studies. Taken together, these two results would provide powerful evidence to suggest that the activation of similar phonetic patterns in the lexicon is an important factor in biasing perception in phoneme identification tasks. These results would also provide further support for the notion that interaction between different levels of linguistic representation is a part of normal speech processing.

The projected results of Experiments 1 and 2 also hold implications for all models of aphasic speech perception. Since Ganong (1980) first described the top-down influence of the lexicon on phonetic categorization in normals, this phenomenon has increasingly been shown to be a strategy employed only when low-level acoustic information is somehow degraded or outside the parameters of natural speech (Burton et al., 1989; McQueen, 1991). The demonstration of a greater lexical or neighborhood density effect for Broca's aphasics would suggest that such top-down influences may also compensate for acquired phonetic impairments, showing an apparent ability of the phonetic perceptual system to reorganize processing in the event of certain types of neurological damage. As well, the results would further serve to distinguish phonetic deficits in Broca's and Wernicke's aphasia and provide evidence that Broca's aphasics utilize heuristic strategies in language processing while Wernicke's aphasics are unable to invoke such lexically-based compensatory mechanisms (as in Blumstein et al., 1991; Blumstein et al., 1994; Milberg et al., 1995).

Experiment 1

Method

Subjects

Three groups of subjects participated in this study: ten non-fluent aphasic patients, seven fluent aphasic patients, and ten elderly control subjects with no history of neurological damage. Two additional nonfluent patients were selected for inclusion in the study but were eliminated from the experiment due to a failure to consistently classify unambiguous /b/ and /p/ stimuli, as required by a pretest (see Procedure section). All subjects were native speakers of English and had no significant hearing impairment. Control subjects were selected from a pool of adult volunteers for language research at the School of Communication Sciences and Disorders, McGill University, and were age-matched to the aphasic subject groups. Control subjects were paid for their participation.

Aphasic subjects met the following medical criteria: a single unilateral stroke in the left hemisphere; a period of at least three months having past since the onset of the stroke. Aphasics were classified as fluent or non-fluent based on the results of testing carried out by speech pathologists involved in the patients' therapy as well as language screenings administered by the experimenters. Test batteries used included the Boston Diagnostic Aphasia Examination (Goodglass & Kaplan, 1983) and the auditory comprehension subsection of the Psycholinguistic Assessment of Language (Caplan & Bub, 1990). Information on all subject groups is presented in Table 1.

Table 1: Background Subject Information

Control Subjects

Subject	Sex	Age
N-1	M	72
N-2	F	71
N-3	M	59
N-4	F	70
N-5	F	67
N-6	F	72
N-7	M	72
N-8	M	63
N-9	M	64
N-10	F	62
	Mean	**66.9**
	SD	**5.5**

Non-Fluent Aphasic Subjects

Subject	Sex	Age	Months Post-Onset of Stroke	Lesion Site	Auditory Comprehension Scores	Diagnosis
NF-1	M	48	100	L parietal	Sentence constrained 18/20 reversible 16/20 Single Word 32/32	Mild nonfluent aphasia
NF-2	F	79	12	L frontoparietal	Sentence constrained 17/20 reversible 13/20 Single Word 32/32	Severe nonfluent aphasia

Table 1. (continued)

NF-3	F	63	11	L frontoparietal	Sentence constrained 17/20 reversible 13/20 Single Word 32/32	Severe nonfluent aphasia
NF-4	F	44	54	L frontoparietal	Sentence constrained 19/20 reversible 17/20 Single Word 31/32	Moderate nonfluent aphasia
NF-5	F	64	32	L fronto-temporo-parietal	Sentence constrained 17/20 reversible 11/20 Single Word 26/32	Severe nonfluent aphasia
NF-6	F	41	114	L frontoparietal	Sentence constrained 20/20 reversible 20/20 Single Word 32/32	Moderate nonfluent aphasia
NF-7	F	68	35	L parietal	Sentence constrained 20/20 reversible 20/20 Single Word 32/32	Moderate nonfluent aphasia
NF-8	M	76	12	L frontal	Sentence constrained 20/20 reversible 13/20 Single Word 32/32	Mild nonfluent aphasia

Table 1. (continued)

NF-9	M	66	57	L MCA distribution	Sentence constrained 15/20 reversible 11/20 Single Word 32/32	Severe nonfluent aphasia
NF-10	F	79	32	L CVA (no CT scan available)	Sentence constrained 20/20 reversible 11/20 Single Word 31/32	Mild nonfluent aphasia
	Mean	**62.8**				
	SD	**14.1**				

Fluent Aphasic Subjects

Subject	Sex	Age	Months Post-Onset of Stroke	Lesion Site	Auditory Comprehension Scores	Diagnosis
F-1	F	82	53	L periventricular	Sentence constrained 19/20 reversible 17/20 Single Word 32/32	Mild fluent aphasia
F-2	F	78	59	L MCA distribution	Sentence constrained 16/20 reversible 18/20 Single Word 32/32	Mild fluent-anomic aphasia

Table 1. (continued)

F-3	M	68	11	CT revealed none	Sentence constrained 20/20 reversible 20/20 Single Word 32/32	Moderate fluent aphasia
F-4	F	78	22	L temporal	Sentence constrained 20/20 reversible 14/20 Single Word 32/32	Moderate fluent aphasia
F-5	M	37	5	L temporo-parietal	Sentence constrained 19/20 reversible 11/20 Single Word 32/32	Mild fluent-conduction
F-6	F	84	28	No CT info available	Sentence constrained 17/20 reversible 14/20 Single Word 32/32	Moderate-fluent-anomic aphasia
F-7	F	73	3	L temporo-parietal hematoma	Sentence constrained 20/20 reversible 17/20 Single Word 29/32	Mild-fluent-anomic aphasia
	Mean	**71.4**				
	SD	**16.1**				

Stimuli

Two test continua were constructed by computer editing natural speech tokens of the syllables /bʊk/, /pʊk/, and /bʊt/. One continuum ranged from the word /bʊk/ to the nonword /pʊk/, and the other ranged from the nonword /bʊt/ to the word /pʊt/. In order to control for the possible contribution of neighborhood density to any findings of a lexical effect (as suggested by Newman et al., in press), the above syllables were selected as continua endpoints because the nonword of each pair had a greater density than its word counterpart. Neighborhood density values were computed as follows: a neighbor of an endpoint stimulus was defined as any word that would result from the addition, deletion or substitution of a single phoneme (Newman et al., in press). Using an online dictionary which contained approximately 20 000 words, the neighbors for each endpoint stimulus were determined. The logarithm of the raw frequency value (Kucera & Francis, 1967) multiplied by ten was computed for each neighbor. These resulting values were then summed to arrive at the frequency-weighted neighborhood density[1]. Neighborhood density values for the four endpoints were as follows: for the /bʊk/ - /pʊk/ continuum, /bʊk/ - 35.49, /pʊk/ - 45.27; for the /bʊt/ - /pʊt/ continuum, /bʊt/ - 43.96, /pʊt/ - 26.97.

The methodology for creating stimuli on the continua was similar to that of Miller and Dexter (1987) and Burton et al. (1989). Naturally produced speech stimuli were recorded by an adult female speaker in a sound-attenuated room using a portable cassette recorder (Sony Professional

Walkman WM-D6C) and a directional microphone (Sony ECM-909); the stimuli were then digitized onto an IBM-compatible computer using the Bliss speech analysis system (Mertus, 1989) at a sampling rate of 20 kHz with a 9.0-kHz low-pass filter and 12-bit quantization.

Waveforms of several recorded productions of the natural speech tokens /bʊk/, /pʊk/ and /bʊt/ were displayed and their individual VOTs were measured. An exemplar token was selected from each of these three groups based on VOT. In order to determine the appropriate VOT step sizes for the /bʊk/ - /pʊk/ continuum, the waveforms of the exemplar /bʊk/ and /pʊk/ tokens were displayed and the difference between their respective VOTs was divided by six, the number of intermediate steps in the continuum. This resulted in an average step size of 6.7 ms. Cursors were then placed on the /bʊk/ waveform at the zero crossings of the vowel closest to the calculated step size intervals. The voiced endpoint of the continuum was the original /bʊk/ token; all other stimuli were created by replacing the burst and the original VOT of the /b/ and a portion of the vocalic segment of the /bʊk/ token with sections of the burst and aspiration noise of the naturally produced /p/ of the /pʊk/ token. Using this methodology, each item on the continuum had the same duration (351.90 ms). Truncating the vowels at zero crossings resulted in progressively shorter vocalic segments as VOT increased. The final continuum consisted of 8 stimuli that ranged in VOT from 12.25 ms at the /b/ end of the continuum to 59.55 ms at the /p/ end of the continuum. Table 2 displays the VOT values and step sizes for the /bʊk/ - /pʊk/ continuum. The /bʊt/ - /pʊt/ continuum was constructed by removing the final /k/ from the /bʊk/ - /pʊk/ continum stimuli and replacing it with a /t/ cut from the naturally-produced speech token /bʊt/. More specifically, the /k/ was excised from /bʊk/ - /pʊk/ stimuli by cutting at the onset of the closure interval. The /t/ from the /bʊt/ token was removed in a similar fashion and was attached to each stimulus from the /bʊk/ - /pʊk/ continuum. This resulted in two continua that shared the same VOT and step size values (see Table 2).

Table 2: Voice Onset Time and Step Sizes (in Milliseconds) of Continua Stimuli

Stimulus Number	Voice Onset Time	Step Size[a]
1	12.25	
2	19.20	6.95
3	25.80	6.60
4	32.50	6.70
5	39.20	6.70
6	45.60	6.40
7	53.20	7.60
8	59.55	6.35

[a]Step size should be approximately 6.70 ms.

Procedure

Since this study involved two experiments, the order of presentation of Experiment 1 and Experiment 2 (see below) was counterbalanced across subjects. For Experiment 1, listeners were run individually and heard both the /bʊk/ - /pʊk/ and the /bʊt/ - /pʊt/ series of continua. The presentation of the two series of continua was blocked, and the order of presentation was counterbalanced across subjects (i.e., within each subject group, half heard the /bʊk/ - /pʊk/ series first, and the other half heard the /bʊt/ - /pʊt/ series first). Each test series was preceded by a set of 15 practice items consisting of the 8 members of the particular continuum presented in order, followed by seven random trials which included endpoint and ambiguous stimuli. Each item on each continuum was presented 10 times in random order for a total of 80 stimuli per test block. Stimuli were presented at intervals of 4.0 seconds (measured from the onset of preceding stimuli) and a 6.0 second interval separated blocks of ten items. There was a minimum delay of 100 ms between a subject's response and the presentation of the following test item.

A pretest was administered to aphasic subjects in order to ensure that they could reliably identify endpoint stimuli before they participated in the actual experiment. Previous studies have shown that these patients may experience difficulty reliably classifying VOT continua stimuli (Blumstein et al., 1994; Blumstein, Cooper, Zurif, & Caramazza, 1977). The pretest consisted of ten occurrences of each of the unambiguous endpoint stimuli from the /bʊk/ - /pʊk/ continuum presented in random order. Aphasic subjects were required to identify each stimulus as "b" or "p" with a minimum of 70% accuracy in order to take part in the experiment.

Test stimuli were presented binaurally to all subjects through headphones (Sony Dynamic Stereo MDR-V1) at a comfortable listening level. Each subject was seated in front of a computer-controlled response box containing two response buttons labelled "b" and "p". Listeners were instructed to identify the first sound of each of the syllables they heard as either "b" or "p" by pushing the corresponding button as quickly and as accurately as possible. Responses were made using one hand and the position of the "b" and "p" buttons was counterbalanced across listeners and continua. Responses and reaction times were recorded by the IBM PC that controlled the experiment.

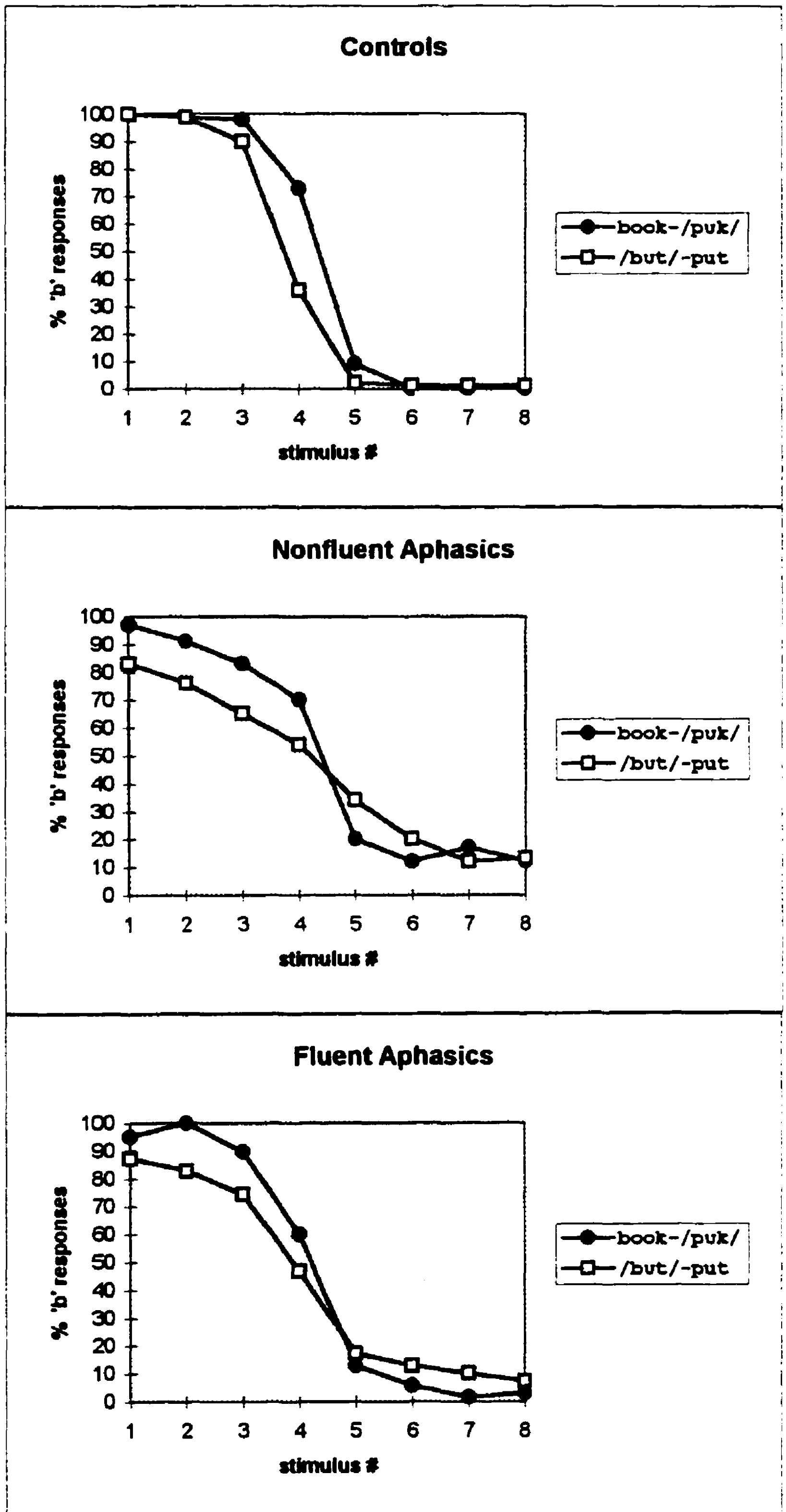
Results

To examine whether lexical status played a role in the categorization of phonemes, category boundaries and percentage of voiced ("b") responses were calculated for each subject. Category boundaries are frequently used in phonetic identification studies to identify shifts in the perception of ambiguous, intermediate stimuli on the continua. Including measures of total voiced responses also allows for the inclusion of any perceptual changes at other points along the continuum (Pitt & Samuel, 1993).

Figure 1 shows the mean identification functions for the "book" - /pʊk/ and the /bʊt/ - "put" continua for the control and aphasic subject groups. As the figure shows, the two functions within each subject group are similar. The functions are also reasonably similar across subject groups, although the aphasics (particularly the nonfluent aphasics) showed some difficulty classifying endpoint stimuli, leading to slightly flatter identification functions than the control subjects. Perusal of the figure reveals a typical lexical effect in the ambiguous stimuli region of the continuum for the control subjects. Both groups of aphasic subjects also show evidence of a lexical effect but the lexical influence is reflected in shifts in the identification function distributed throughout the continuum.

Category boundaries were calculated for each subject for each continuum by fitting a linear regression line to the data in the boundary regions

Figure 1.
Mean Identification Functions for Normal and Aphasic Subject Groups



of the continua in order to determine the stimulus number corresponding to 50% voiced responses (as per Miller & Dexter, 1988). Individual category boundaries and percentages of voiced responses corresponding to the two continua are displayed in Table 3, along with the means for each subject group.

Table 3.
Overall Category Boundaries and Percentage of "b" Responses

		book-/puk/		/but/-put	
Controls		Stimulus #	% 'b' Responses	Stimulus #	% 'b' Responses
1		4.27	48.75	3.80	40.00
2		4.73	51.25	4.44	47.50
3		4.73	51.25	2.84	28.21
4		4.36	47.50	3.73	38.75
5		3.80	38.75	3.73	38.75
6		4.21	47.50	4.07	46.25
7		4.06	46.25	3.79	43.04
8		3.80	40.00	3.93	42.50
9		4.27	48.75	3.71	41.25
10		4.73	53.75	4.36	47.50
	mean	4.30	47.37	3.84	41.37
Nonfluent Aphasics					
1		3.97	45.00	3.95	46.25
2		6.09	68.75	4.73	51.25
3		4.62	50.00	4.94	53.75
4		*	63.75	*	47.50
5		2.03	40.00	*	27.50
6		3.43	37.50	2.32	22.50
7		4.71	56.25	4.65	53.75
8		4.17	47.50	4.21	45.00
9		4.08	46.25	4.16	46.25
10		4.43	48.75	4.77	52.50
	mean	4.44	50.37	4.22	44.62
Fluent Aphasics					
1		5.03	55.00	4.80	52.50
2		3.48	33.77	2.68	26.25
3		5.12	56.25	2.42	27.50
4		3.65	40.00	5.21	55.55
5		4.21	45.00	4.12	43.75
6		3.83	41.25	*	48.75
7		4.50	50.00	3.73	38.75
	mean	4.33	45.90	3.83	41.86

*category boundary could not be computed

It will be noted that, within the patient groups, several boundary values are not indicated. As illustrated in Figure 2, nonfluent subjects 4 and 5 and fluent subject 6 produced identification functions for one or both continua that did not permit the calculation of boundary values due to inconsistent responses at the endpoints or across the continuum. Hence, these subjects' results for both continua were not included in calculation of the group means. The average boundary shift (in stimulus steps) for normals (0.46) and for fluent aphasics (0.50) was comparable; as a group, the nonfluent aphasics displayed a smaller shift of 0.22 steps. All shifts were towards a lexical effect with higher boundary values for the "book"-/pʊk/ continuum relative to the /bʊt/-"put" continuum. Table 4 shows the VOT values that correspond to the category boundaries listed in Table 3. All boundary value were within a similar range and were consistent with a typical VOT boundary for labial stops in English (Lisker & Abramson, 1964). The boundary shifts for all groups were quite small, with controls showing a 3.05 ms shift, nonfluent aphasics a 1.44 ms shift, and fluent aphasics a 3.37 ms shift.

Figure 3 displays the within-group differences in percentage of voiced responses for the two continua. Similar to the boundary values, all differences in percentage of voiced responses were in the direction of a lexical effect, with a greater percentage of voiced responses to the "book" - /pʊk/continuum than the /bʊt/ - "put" continuum. Controls showed a 6.00% difference, nonfluent aphasics a 5.75% difference, and fluent aphasics a 4.04% difference. Interestingly, the lexical influence was more comparable across groups when

Figure 2.
Functions for which Category Boundaries Could Not Be Computed

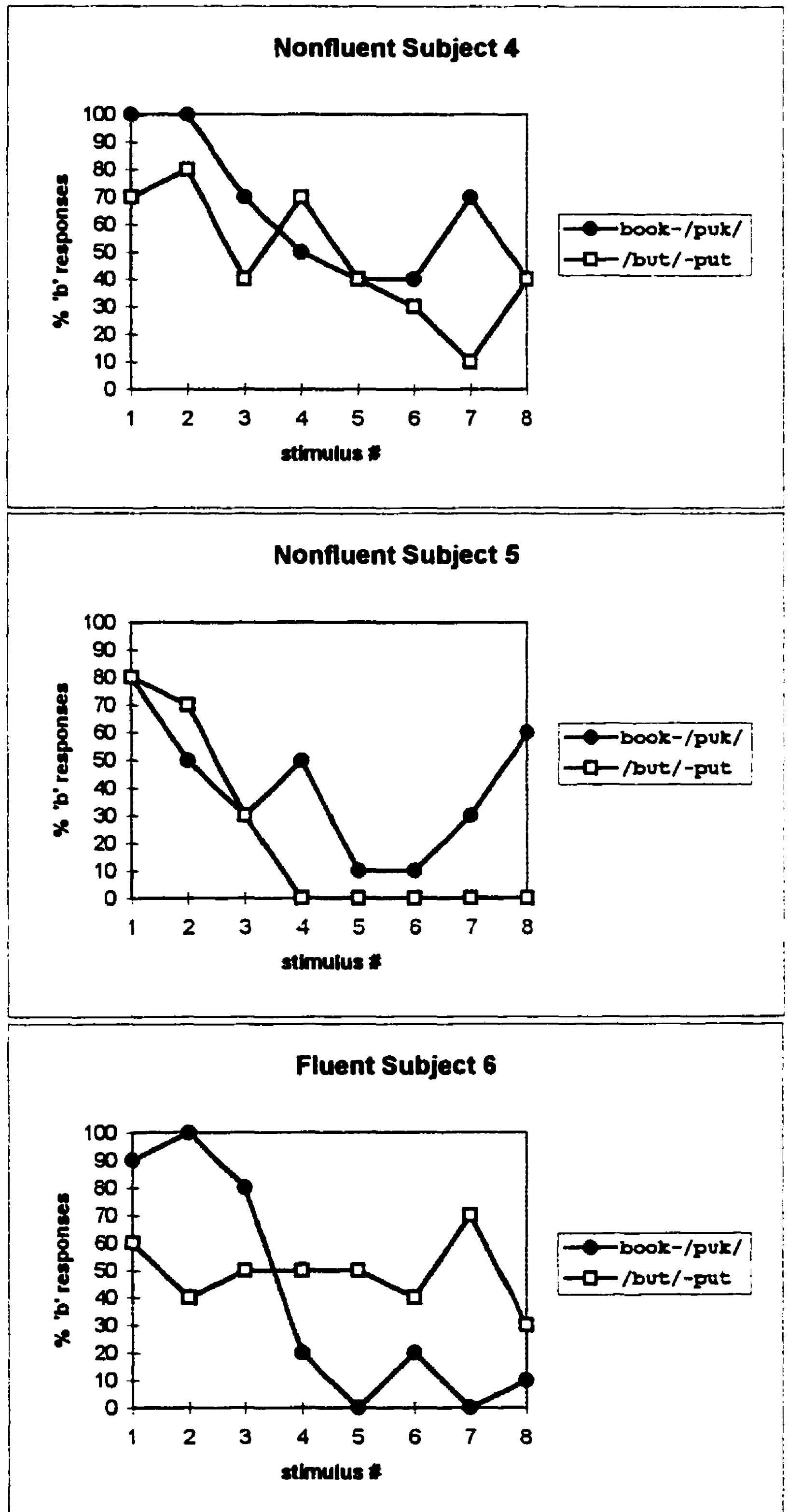
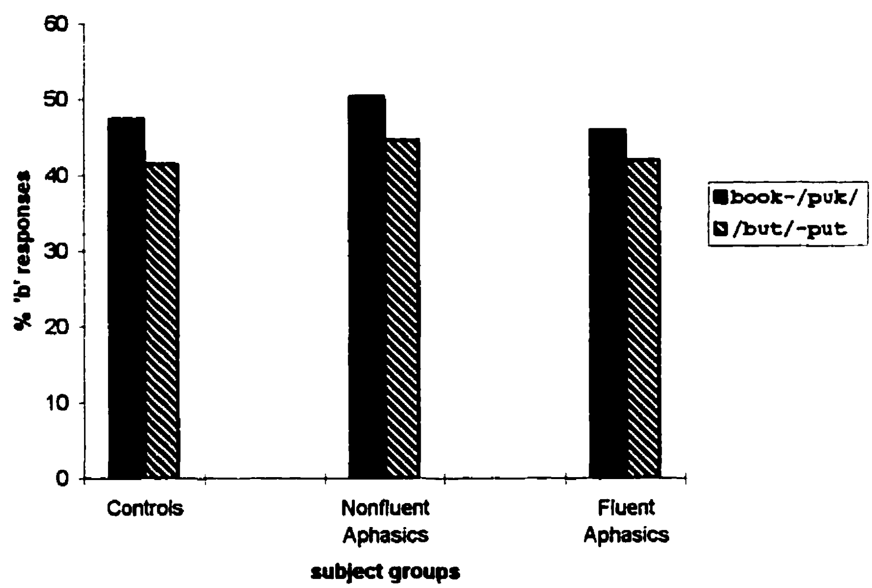


Table 4.
VOT Phonetic Boundaries (in msec)

		book-/puk/	/but/-put
Controls			
1		34.31	31.16
2		37.39	35.45
3		37.39	24.74
4		34.91	30.69
5		31.16	30.69
6		33.91	32.97
7		32.90	31.09
8		31.16	32.03
9		34.31	30.56
10		37.39	34.91
	mean	34.48	31.43
Nonfluent Aphasics			
1		32.30	32.16
2		46.28	37.39
3		36.65	38.80
4		*	*
5		19.40	*
6		28.68	21.31
7		37.26	36.85
8		33.64	33.91
9		33.04	33.57
10		35.38	37.66
	mean	35.4	33.96
Fluent Aphasics			
1		39.39	37.86
2		29.02	23.69
3		39.97	21.97
4		30.15	40.54
5		33.91	33.30
6		31.36	*
7		35.85	30.69
	mean	34.71	31.34

*phonetic boundary could not be computed

Figure 3.
Percentage of 'b' Responses to the Two Test Continua



calculated as a function of percentage voiced responses than in terms of boundary values.

In order to determine if any of the above differences reached significance, separate two-way repeated measures analyses of variance (ANOVAs) (Group x Continuum) were conducted on boundary values and percentage of "b" responses. Due to unequal group sizes, the data were first transformed by taking the logarithms of boundary values and the arcsines of percentages. The ANOVAs revealed a significant effect of Continuum for both category boundaries ($F(1,21) = 5.482$, $p < .03$) and percentage of "b" responses ($F(1,24) = 7.433$, $p < .02$). These effects indicate that the lexical influence displayed in the raw data was significant. No other main effects or interactions reached significance.

Following Fox (1984; see also Blumstein et al., 1994; Burton et al., 1989; Newman et al., in press), response data were then partitioned into three RT ranges -- fast, intermediate and slow. Ranges were established for each individual subject by dividing their total set of 80 responses into thirds (as per Miller & Dexter, 1988). Thus, the fast RT range contained the fastest 27 responses, the intermediate RT range contained the next fastest 27 responses, and the slow RT range was comprised of the remaining 26 responses. Such partitioning is important in the present study since it has been suggested that lexical and neighborhood effects may emerge at different temporal processing points in phoneme identification tasks (Newman et al., 1996). Table 5 displays the average RT range values (in msec) for the three groups. Not surprisingly, the RT ranges are higher (i.e. slower) for both patient groups relative to the normal controls.

Table 5.
Average Reaction Time Ranges (in msec)

		book-/puk/	/but/-put
Controls	FAST	477-702	493-722
	INTERMEDIATE	703-852	723-915
	SLOW	>852	>915
Nonfluent Aphasics	FAST	581-949	577-980
	INTERMEDIATE	950-1203	981-1279
	SLOW	>1203	>1279
Fluent Aphasics	FAST	577-936	555-937
	INTERMEDIATE	937-1166	938-1234
	SLOW	>1166	>1234

Figure 4 shows the mean identification functions of all subject groups for the three response ranges. The controls show a tendency towards a lexical effect in the ambiguous boundary region (stimuli # 3, 4, and 5) in each of the three RT ranges. This contrasts with both the fluent and nonfluent aphasic groups, who seem to show a less consistent lexical influence in the different RT ranges across the continuum.

Tables 6, 7 and 8 display the individual and average boundary values and percentage of voiced responses for the three RT ranges. Once again, boundary values for some patients could not be computed due to erratic, or

Figure 4.
Mean Identification Functions for Fast, Intermediate, and Slow Response Ranges

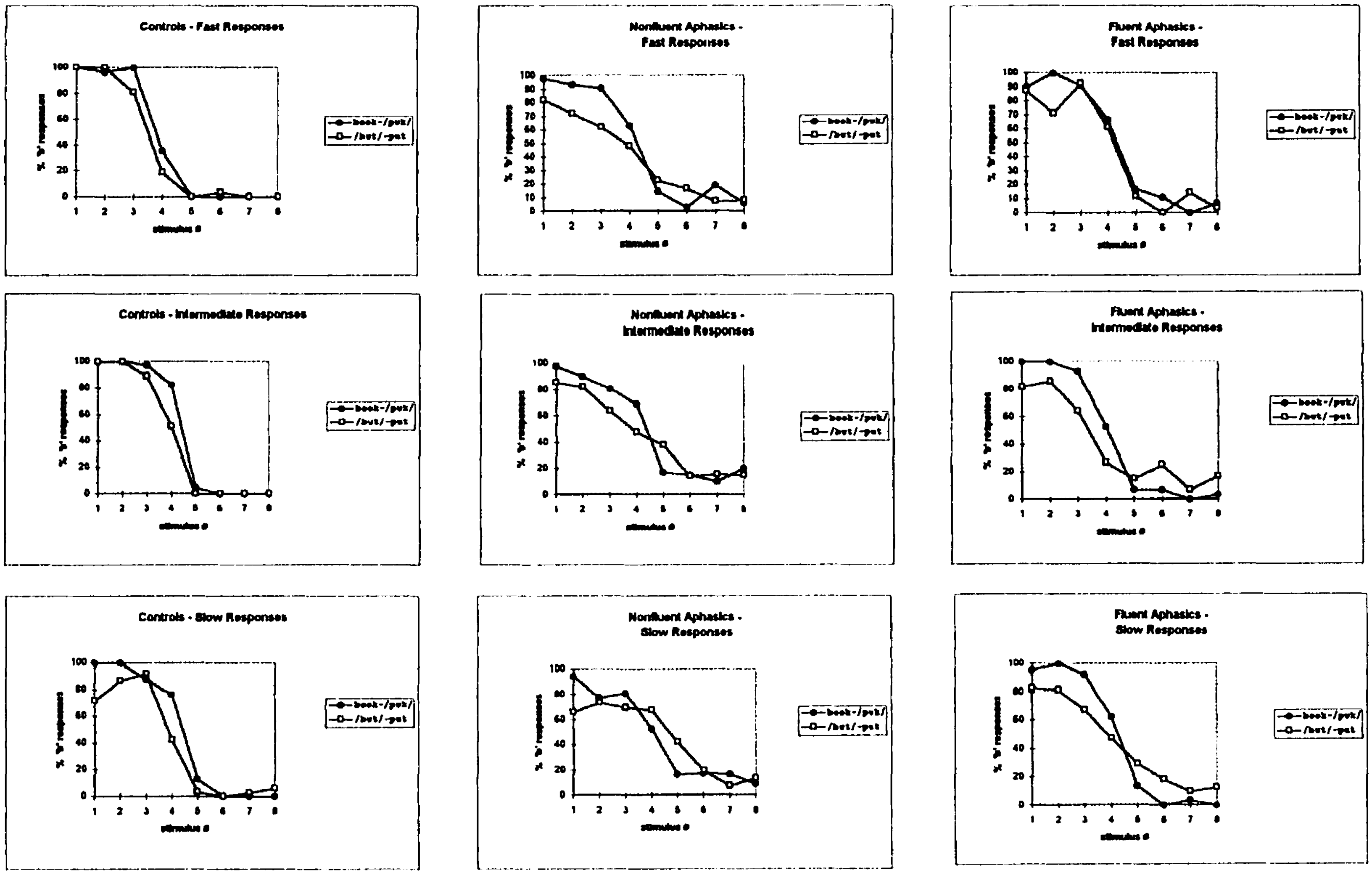


Table 6.
Category Boundaries and Percentage of "b" Responses for Fast RT Range

	book-/puk/		/but/-put	
	Stimulus #	**% 'b' Responses**	**Stimulus #**	**% 'b' Responses**
Controls				
1	4.00	57.14	2.50	28.57
2	4.50	62.96	4.87	53.85
3	3.50	33.33	2.00	7.41
4	3.50	55.55	3.50	62.96
5	2.89	29.63	4.00	42.86
6	3.50	62.96	4.00	51.85
7	4.50	51.85	3.00	40.74
8	3.50	51.85	3.50	66.67
9	4.00	44.44	3.00	44.44
10	3.50	29.63	4.50	51.85
mean	3.74	47.93	3.49	45.12
Nonfluent Aphasics				
1	4.50	59.26	3.57	40.74
2	5.50	77.78	3.27	44.44
3	4.83	51.85	4.80	48.15
4	*	59.26	*	62.96
5	2.31	44.44	*	11.11
6	3.12	37.04	2.50	33.33
7	5.45	66.66	4.17	67.86
8	4.17	44.44	3.50	29.63
9	3.88	40.74	3.91	44.44
10	4.11	62.96	4.00	62.96
mean	4.44	54.44	3.71	44.56
Fluent Aphasics				
1	5.50	62.96	5.00	55.55
2	*	11.11	*	0.00
3	5.50	85.19	4.00	62.96
4	3.50	59.26	4.50	25.93
5	4.50	70.37	4.50	59.26
6	*	70.37	*	40.74
7	3.50	55.56	3.50	55.55
mean	4.50	67.28	4.30	50.00

*category boundary could not be computed
Note: fluent subject 2 was not included in calculation of the group means

Table 7.
Category Boundaries and Percentage of "b" Responses for Intermediate RT Range

	book-/puk/		/but/-put	
	Stimulus #	% 'b' Responses	Stimulus #	% 'b' Responses
Controls				
1	4.50	48.15	4.00	33.33
2	4.50	59.26	4.50	33.33
3	4.50	59.26	2.83	44.44
4	4.73	44.44	3.50	18.52
5	3.50	44.44	3.50	34.62
6	4.50	25.93	4.50	51.85
7	3.58	33.33	4.17	46.15
8	4.00	44.44	3.89	32.14
9	4.50	51.85	3.50	33.33
10	4.00	62.97	4.50	55.56
mean	4.23	47.41	3.89	38.33
Nonfluent Aphasics				
1	3.50	33.33	*	48.15
2	6.01	66.67	*	59.26
3	4.50	51.85	4.57	51.85
4	*	74.07	3.46	44.44
5	*	37.03	*	37.03
6	3.17	40.74	1.67	14.81
7	5.00	66.66	4.70	46.15
8	4.50	44.83	3.50	37.04
9	4.33	37.04	3.83	44.44
10	4.14	44.44	5.50	59.26
mean	4.27	49.67	3.96	44.24
Fluent Aphasics				
1	4.82	53.57	4.00	50.00
2	2.78	42.86	2.50	33.33
3	5.31	55.56	*	7.41
4	3.89	18.52	5.62	74.07
5	3.50	22.22	4.00	44.44
6	3.37	22.22	*	55.56
7	4.50	55.55	3.50	22.22
mean	3.90	38.46	3.92	41.00

*category boundary could not be computed

Table 8.
Category Boundaries and Percentage of "b" Responses for Slow RT Range

	book-/puk/		/but/-put	
	Stimulus #	% 'b' Responses	Stimulus #	% 'b' Responses
Controls				
1	4.50	57.14	3.51	60.00
2	4.78	30.77	4.10	53.85
3	4.80	61.54	2.56	33.33
4	4.17	55.56	3.51	34.62
5	3.83	44.00	3.76	38.46
6	4.25	53.85	4.23	42.86
7	4.17	30.77	4.11	42.31
8	3.42	23.08	4.17	26.92
9	4.26	44.44	3.96	46.15
10	5.07	69.23	4.35	34.62
mean	4.32	47.04	3.83	41.31
Nonfluent Aphasics				
1	3.34	42.31	4.50	50.00
2	*	61.54	*	50.00
3	4.24	46.15	5.29	61.54
4	5.81	57.69	*	34.62
5	*	38.46	*	34.62
6	3.48	34.62	1.19	19.23
7	4.99	34.62	5.46	46.15
8	4.24	54.17	4.54	69.23
9	4.65	61.54	5.08	50.00
10	4.87	38.46	4.35	34.62
mean	4.26	46.96	4.34	45.00
Fluent Aphasics				
1	4.76	46.15	4.78	52.00
2	3.88	50.00	2.95	46.15
3	4.81	26.92	*	11.54
4	3.86	44.44	6.62	73.91
5	4.37	42.31	3.86	26.92
6	3.20	26.92	*	50.00
7	4.49	38.46	3.80	38.46
mean	4.27	39.31	4.40	42.71

*category boundary could not be computed

relatively flat, identification functions. A greater number of such functions emerged in the partitioned RT ranges due to the fact that each range typically contained only 26 or 27 responses (as opposed to 80 in the overall response set). As may be seen from the Tables, several individual subjects within the patient groups failed to display the normal lexical effect, particularly in the intermediate and slow RT ranges.

Separate two-way (Group x Continuum) ANOVAs were run on transformed category boundary and percentage of "b" response values in each RT range for a total of six ANOVAs. It should be noted that fluent aphasic subject 2 showed no "b" responses for the /bʊt/ - "put" continuum in the fast RT range. Hence, this subject's data were not included in that analysis. The only significant result to emerge was a main effect of Continuum in the fast range for percentage of "b" responses ($F(1,24) = 11.391$, $p < .004$) indicating significantly more "b" responses to the "book" - /pʊk/ continuum than the /bʊt/ - "put" continuum. In addition, there was a trend toward an effect of Continuum ($F(1,20) = 3.471$, $p = .077$) in the fast range for the category boundary values; there was also a trend toward an effect of Group ($F(2,20) = 3.114$, $p = .066$) in that analysis with both groups of aphasic patients displaying somewhat higher crossover boundaries than the normal controls.

Discussion

The present experiment set out to determine if the characteristics of the neighborhoods of word and nonword endpoints used in a phonetic identification task would influence the appearance of a lexical effect for elderly normal and aphasic subjects. Also of interest were any differences which might materialize in the appearance or size of the lexical effect between fluent and nonfluent aphasic patients and normal subjects (cf. Blumstein et al., 1994).

The overall response data for all groups showed that the lexical status of endpoint stimuli did indeed influence the identification of phonemes, with more voiced responses for the "book" - /pʊk/ continuum than the /bʊt/ - "put" continuum. This result is in agreement with several other studies that have been conducted with young normals, showing that lexical status may act in a top-down fashion to influence the identification of phonemes (Burton et al., 1989; Connine & Clifton, 1987; Fox, 1984; Ganong, 1980; Miller & Dexter, 1988; McQueen, 1989, 1991; Pitt & Samuel, 1993; Reed, 1989). The present study showed an overall lexical effect reflected in both category boundaries and percentage of voiced responses, indicating that the lexical effect was especially strong in the intermediate, ambiguous stimuli region, but also emerged when responses across all steps of the continua were considered.

As was illustrated in Figure 1, elderly normal subjects showed a lexical influence almost exclusively in the ambiguous boundary region and not across the continuum, consistent with previous findings (Ganong, 1980). Although no significant interaction emerged, visual inspection of the data suggests that the lexical influence which emerged across the continuum (in the statistical analysis of percentage of voiced responses) was primarily due to the performance of both aphasic patient groups and is most likely a result of their generally greater difficulty in making phonetic judgements (Gow & Caplan, 1996). Since these subjects exhibit less than perfect identification scores at the endpoints of the continua, lexical status seems to play a role even for endpoint stimuli which are typically unambiguous for normal listeners (cf. Blumstein et al., 1994). Perhaps with larger subject groups, a difference in the utilization of lexical status between normal and aphasic subjects would have emerged statistically.

The identification functions displayed by the aphasic groups were somewhat surprising in that the fluent aphasic subjects seemed to show less difficulty in making phonetic judgements than the nonfluent aphasics. This is inconsistent with previous investigations which demonstrated that nonfluent Broca's aphasics show less impairment in phoneme discrimination as compared to fluent Wernicke's aphasics (Blumstein et al., 1977). Still, acoustic-phonetic deficits are certainly not uncommon among nonfluent aphasics. For instance, Basso et al. (1977) found that 17/29 nonfluent aphasics showed deficits on a phoneme discrimination task. Thus, it is certainly possible that the 10 nonfluent aphasic subjects who participated in the present study had a greater overall degree of acoustic-phonetic impairment than the 7 fluent patients. It is also notable that the fluent aphasic group in the present study was not strictly composed of Wernicke's aphasics but included 2 subjects who were also listed as anomic, and 1 who was diagnosed as a Wernicke/Conduction aphasic. Thus, the underlying deficits of aphasic subjects who are classified as "fluent" may differ from one study to another. In any case, it should be noted that despite an apparent difference in phonetic perception ability for the aphasic groups, a Group x Continuum interaction did not emerge in the overall data, indicating that differences in identification functions between groups were not statistically significant.

When the data were partitioned into RT ranges, the only significant result to emerge was a lexical effect across groups in the fast range. This finding is inconsistent with previous studies showing that the lexical effect is limited to intermediate and slow RT ranges for normal subjects (Burton et al., 1989; Fox, 1984; Miller & Dexter, 1987). A number of methodological issues may account for this inconsistency. First, it should be noted that category boundaries and percentage of voiced responses for individual subjects in each RT range in the present study were based on only 27 responses to each continuum. It is possible that this relatively small sample may have been a factor in the lack of a significant lexical effect emerging in the intermediate and slow ranges. Nevertheless, Burton et al. (1989) had a similarly small number of responses in their RT ranges and still found a lexical effect solely in the slow RT range, consistent with Fox (1984). Further, the studies mentioned above employed young normal subjects. Obviously, it would be imprudent to compare these previous results with the present findings which include data for aphasic patients. A more relevant comparison between previous reports of the lexical effect and the present overall findings may be made by focusing only on the results of the normal control subjects, bearing in mind the older average age of individuals in the current study.

As was illustrated in Figure 4, the control subject group showed evidence of a lexical influence in all three RT ranges (which did not consistently reach significance). Although, as noted above, a lexical effect was not expected in the fast range, there are discrepancies between the absolute values defining the RT ranges used in the present study, and the corresponding ranges employed in previous studies. For example, Fox (1984) imposed set RT ranges on his data, with the fast range including responses with reaction times of 500ms or less, the intermediate range including responses between 500ms and 800ms, and the slow range corresponding to responses greater than or equal to 800ms. In contrast, Miller and Dexter (1987) created RT ranges by dividing each individual subject's response set into thirds. Such a partitioning resulted in fast ranges that had upper boundaries ranging from 394 to 555ms and intermediate ranges whose upper boundaries ranged from 484 to 678ms. Although RT ranges in the present study were created in the same manner as in Miller and Dexter's study, a comparison of the average ranges employed for the controls here (Fast 477-702ms, Intermediate 703-852, Slow > 852ms) to those in earlier studies reveals that the majority of fast responses for the normal control subjects would fall into Fox's and Miller and Dexter's intermediate ranges, in which lexical effects emerged. Likewise, the slow ranges utilized by both Fox and Miller and Dexter have roughly the same lower time boundaries as the intermediate range in the present study. Hence, the lexical influence that seemingly emerges earlier than would be expected with the control group is actually on par with the absolute time course of the lexical effect outlined in previous studies (Fox, 1984; Miller & Dexter, 1987; see further discussion below).

The large difference in RT range limits between this study and previous investigations of the lexical effect is most likely due to the older age of the control subjects utilized here. It should be noted that the only previous examination of the lexical effect with elderly normals did find an effect of lexical status on phonetic identification, but did not partition data into RT ranges in order to investigate its possible time course (Blumstein et al., 1994). Thus, our initial hypothesis concerning the time course of the lexical effect was based on previous findings for young normals; paralleling those studies, it was anticipated that a lexical effect would emerge primarily in the intermediate and slow RT ranges (Burton et al., 1989; Fox, 1984; Miller & Dexter, 1987). As noted earlier, the RT ranges in the present study were determined for each subject separately in order to account for individual processing times. The rationale behind using this kind of partitioning in previous studies has been that language processing times on this type of a task are relational -- the fastest third of the response set for one subject will tap the same processes as the fastest third of another subject's set, even though both of these "fast" sets may reflect different absolute time ranges (Burton et al., 1989; Miller & Dexter, 1988). However, it is conceivable that the fast, intermediate, and slow RT ranges for young and elderly normals do not necessarily reflect the same language processes, due to changes in processing that may accompany aging (Klatzky, 1988; Salthouse, 1988; Wingfield, Poon, Lombardi, & Lowe, 1985).

Fox (1984) suggested that the reason why lexical status fails to play a role for fast responses is because the lexical effect reflects a post-perceptual correction process on an initial phonetic judgement, and that responses that fall in the fast RT range are made before these correction processes are given a chance to act. Thus, the phonetic judgements included within the fast range are made by subjects based only on acoustic-phonetic information in the speech signal. But in the case of elderly subjects, it is not clear that their overall slower RTs reflect a general delay in all levels of language processing, which would render their fast, intermediate, and slow RT ranges comparable to younger subjects. In fact, longer latencies for these subjects may result from greater difficulties in perceiving or assimilating acoustic-phonetic information and a greater reliance on context in language processing (Wingfield et al., 1985). Bergman et al. (1978) found that older adults who had otherwise normal hearing showed poorer results on a speech intelligibility task for both distorted and undistorted sentences than young adults. If these subjects are experiencing some difficulty in making phonetic categorizations based only on acoustic information, they may display slower response times than normal subjects. Further, this longer delay may allow them to utilize lexical influences in making their phonetic judgements, with the result that a lexical effect emerges in their "fast" responses. Moreover, since the influence of lexical status has been shown to be especially strong in cases where acoustic information is somehow ambiguous or distorted (Burton et al., 1989; Ganong, 1980), it would not be surprising for a lexical effect to even emerge in the fast range if subjects are experiencing a large degree of uncertainty in their phonetic judgements.

Turning to the intermediate and slow RT data for the control group, the identifications once again reveal a shift in functions in the direction of a lexical effect. The lack of a statistically significant lexical effect for both of these ranges is primarily due to the inconsistency in the performance of the aphasic patient groups, as is evident in Tables 7 and 8. In fact, the normal controls show a greater average difference in boundary values and percentage of voiced responses in the intermediate range, as compared to their response pattern in the fast range. Although the lexical effect could not be evaluated statistically in the intermediate and slow ranges for the normal controls alone, both response patterns again suggest lexical influences consistent with the time course reported in previous studies (Burton et al., 1989; Fox, 1984; Miller & Dexter, 1987) and indicative of a lexical effect across all RT ranges. It should also be remembered that the present experiment sought to determine if differences in the emergence of the lexical effect would be apparent when the neighborhood density of the endpoints was controlled. This may also have been a factor in the somewhat unexpected RT range results. This possibility will be addressed in greater detail below.

With regard to the performance of the aphasic patients, it will be recalled that a phonetic identification study conducted by Blumstein et al. (1994) found a larger lexical effect for nonfluent aphasics as compared to normal subjects, and no effect of lexical status for fluent aphasics. Similar differences between subject groups in the size and appearance of the lexical effect did not materialize in the present study. Curiously, fluent aphasics showed an influence of lexical status in both their overall results and through all RT ranges (though the intermediate and slow RT range lexical effects did not reach significance). There are at least two factors that may account for these apparently conflicting results.

An examination of the individual patient characteristics for the fluent aphasic subjects in the two studies points to some differences in the time period post-onset of aphasic symptoms between the two groups. Blumstein et al.'s (1994) fluent aphasic group included 4 out of 6 subjects who were 8 months or less post-onset, with a mean of 13 months post-onset for the entire group. This is different from the fluent aphasic group in the present study in which only 2 of 7 subjects were less than 8 months post-onset, with an average of 26 months post-onset for the group. It is notable that the two subjects in Blumstein et al.'s study who had the longest post-onset time (36 and 24 months), also showed the greatest shift in phonetic boundaries toward a lexical effect (7.1 and 6.9ms, respectively, in comparison to the group mean of 0.2ms). Thus, these patients may be more characteristic of the individuals comprising the fluent aphasic group in the present study, who showed a lexical effect. At the same time, it should be remembered that sample sizes in both studies were relatively small, rendering both results speculative.

Another possible factor in the discrepant results for the fluent aphasic patients relates to specific stimuli utilized in each study. While the /b/ - /p/

contrast was employed in the present study, Blumstein et al. used /d/ - /t/ VOT continua to examine the lexical effect. Although there is no obvious reason why the lexical effect might occur with some phonetic contrasts and not others, Pitt and Samuel (1993) noted that the greatest amount of variability in the emergence of the lexical effect occurs with the /d/ - /t/ contrast. Blumstein et al. (1994) not only failed to find a lexical effect for fluent aphasics, but also found no effect for young normals. Thus, the variability in the emergence of the lexical effect that is associated with this phonetic contrast may have been an additional factor in the failure of the fluent aphasics in Blumstein et al.'s study to show any influence of lexical status.

While it was initially predicted that the fluent aphasic group in the present experiment would show no lexical effect in their phonetic categorizations, it was also predicted that the nonfluent aphasics would show a greater lexical influence than the normal control group, based on Blumstein et al.'s findings (1994). Although the nonfluent aphasics did show an effect of lexical status, no Group x Continuum interaction emerged in either the overall or the partitioned data, suggesting that the lexical influence was no greater for these patients than normal subjects or fluent aphasics. The discrepancies between Blumstein et al.'s findings for nonfluent aphasics and the present results may, in fact, be more apparent than real. The primary motivation for the present experiment was to examine the potential role of neighborhood density in phonetic identification of word-nonword continua. As will be explained further below, it is possible that neighborhood activation of the nonword endpoints may have overriden the lexical influence for these patients, reducing the lexical effect shown by the nonfluent aphasics.

Recall that we attempted to neutralize any possible contribution of neighborhood density to a lexical effect by constructing word-nonword continua that had roughly equivalent density values. Since word-nonword and nonword-word combinations differing only in an initial /b/ - /p/ contrast which met these neighborhood criteria could not be found, it was instead ensured that the nonword endpoints had the greater neighborhood density values. As it turned out, the only appropriate stimuli that could be found had rather large differences in neighborhood density. In the "book" - /pʊk/ continuum, /pʊk/ was greater in neighborhood density than "book" by a value of 9.77. In the /bʊt/ - "put" continuum, /bʊt/ was greater in neighborhood density than "put" by a value of 17.00. If neighborhood density acts concurrently or prior to a lexical influence in biasing phonetic judgements, it is possible that these disparities in the density values of the endpoints may have reduced some or all of the lexical effects in this experiment. For example, upon hearing a perceptually ambiguous stimulus, two phonological similarity neighborhoods corresponding to the continuum endpoints become active in a subject's lexicon. If a subject responds at a processing point prior to which the word endpoint reaches a predesignated recognition threshold, then the biasing influence on a phonetic judgement will be the more active lexical neighborhood (which, in this experiment, corresponds to the nonword endpoint). Alternatively, if a subject responds after the word endpoint has reached a recognition threshold, lexical status will be the dominating influence on phonetic judgements. It is assumed that neighborhood density would not exert an influence after word recognition, since word recognition is a product not only of increased activation of a single lexical item, but also a corresponding inhibition of lexical neighbors (Luce, et al., 1990). Thus, there may be two separate lexical influences working in opposing directions in this experiment. The determination of which type of influence may bias an individual phonetic judgement is dependent upon the processing point at which a subject responds.

Proposing that the similarity neighborhoods of continua endpoints in the present experiment may be a counteracting force to the lexical effect does not necessarily imply that normal subjects and fluent and nonfluent aphasics are equally susceptible to the influence of neighborhood density. In fact, it is possible that neighborhood density may exert a greater influence on nonfluent aphasic subjects than fluent aphasics or normal controls. Blumstein et al. (1994) have suggested that nonfluent aphasics are more likely than normals or fluent aphasics to utilize heuristic strategies in language processing (see also Blumstein et al., 1982; Milberg & Blumstein, 1981). Thus, it would not be surprising for these patients who have formerly shown larger lexical effects than normals in phonetic identification (Blumstein et al., 1994) to also show a greater influence of neighborhood density. If this, indeed, were the case, a larger effect of lexical status than that seen in the normal subject group may have been masked in the statistical analysis by a reverse bias of neighborhood density. At present, such a hypothesis remains speculative. In order to assess this hypothesis, Experiment 2 more precisely examines the possibility that neighborhood density may differentially influence phonetic identification for normal and aphasic subjects.

Experiment 2

Method

Subjects

Subject groups were the same as those used in Experiment 1 (see Table 1).

Stimuli

Two test continua were constructed by computer editing natural speech tokens of the syllables /beθ/, /peθ/, and /beʃ/. One continuum ranged from /beθ/ to /peθ/ and the other ranged from /beʃ/ to /peʃ/. The basis for choosing these particular nonword syllables as endpoints was their relative neighborhood density values. In the /beθ/ - /peθ/ continuum, the voiced endpoint /beθ/ had the greater neighborhood density (/beθ/ - 29.7, /peθ/ - 25.6). In the /beʃ/ - /peʃ/ continuum, the voiceless endpoint /peʃ/ had the greater density (/beʃ/ - 18.9, /peʃ/ - 23.5).

The equipment and methodology used for creating continua stimuli were similar to Experiment 1. Waveforms of several natural recorded productions of the speech tokens /beθ/, /peθ/, and /beʃ/ were displayed and their respective VOTs were measured. From each of these groups of productions, an exemplar token was selected based on VOT. In order to determine the appropriate VOT step sizes for the /beθ/ - /peθ/ continuum, the waveforms of the selected /beθ/ and /peθ/ tokens were displayed and the difference between their respective VOTs was divided by six, the number of intermediate steps in the continuum.

This resulted in an average step size of 7.9 ms. Cursors were then placed on the /beθ/ waveform at the zero crossings of the vowel closest to the calculated step size intervals. The voiced endpoint of the continuum was the original /beθ/ token; all other stimuli were created by replacing the burst and the original VOT of the /b/ and a portion of the vocalic segment of the /beθ/ token with sections of the burst and aspiration noise of the naturally produced /p/ of the /peθ/ token. Using this methodology, each item on the continuum had the same duration (457.20 ms). Truncating the vowels at zero crossings resulted in progressively shorter vocalic segments as VOT increased. The final continuum consisted of 8 stimuli that ranged in VOT from 8.00 ms at the /b/ end of the continuum to 62.90 ms at the /p/ end of the continuum. Table 9 displays the VOT values and step sizes for the /beθ/ - /peθ/ continuum.

Table 9: Voice Onset Time and Step Sizes (in Milliseconds) of Continua Stimuli

Stimulus Number	Voice Onset Time	Step Size[a]
1	8.00	
2	15.65	7.65
3	23.35	7.70
4	31.55	8.20
5	39.40	7.85
6	47.40	8.00
7	55.45	8.05
8	62.90	7.45

[a]Step size should be approximately 7.9 ms.

The /beʃ/ - /peʃ/ continuum was constructed by removing the final /θ/ from the /beθ/ - /peθ/ continuum stimuli and replacing it with a /ʃ/ cut from the naturally produced speech token /beʃ/. This resulted in two continua that shared the same VOT and step size values (see Table 9).

Procedure

The procedure was identical to Experiment 1. The presentation of the continua stimuli was blocked and the order was counterbalanced across listeners with half hearing the /beθ/ - /peθ/ series first, and the other half hearing the /beʃ/ - /peʃ/ series first.

Results

As in Experiment 1, category boundaries and percentage of "b" responses were computed to determine if the identification of phonemes varied as a function of VOT continuum. Figure 5 shows the mean identification functions for the /beθ/-/peθ/ and /beʃ/-/peʃ/ continua for the three subject groups. Within each group, the two functions are very similar. Across subject groups, the control and fluent aphasics' identification functions have roughly categorical shapes, although the fluent patients' functions are a little less steep due to difficulty in classifying endpoint stimuli. This is true to an even greater extent for the nonfluent aphasics, who show considerably flatter identification functions than normal subjects. All three subject groups show a tendency towards a neighborhood effect, with more "b" responses to the /beθ/-/peθ/ continuum than the /beʃ/-/peʃ/ continuum; the greatest neighborhood effect is displayed by the fluent aphasic group.

Category boundaries for each subject for each continuum were calculated by the same method as in Experiment 1. These values, along with the percentage of "b" responses and the means for each subject group for the two continua are displayed in Table 10. As is apparent from the Table, several

Figure 5.
Mean Identification Functions for Normal and Aphasic Subject Groups

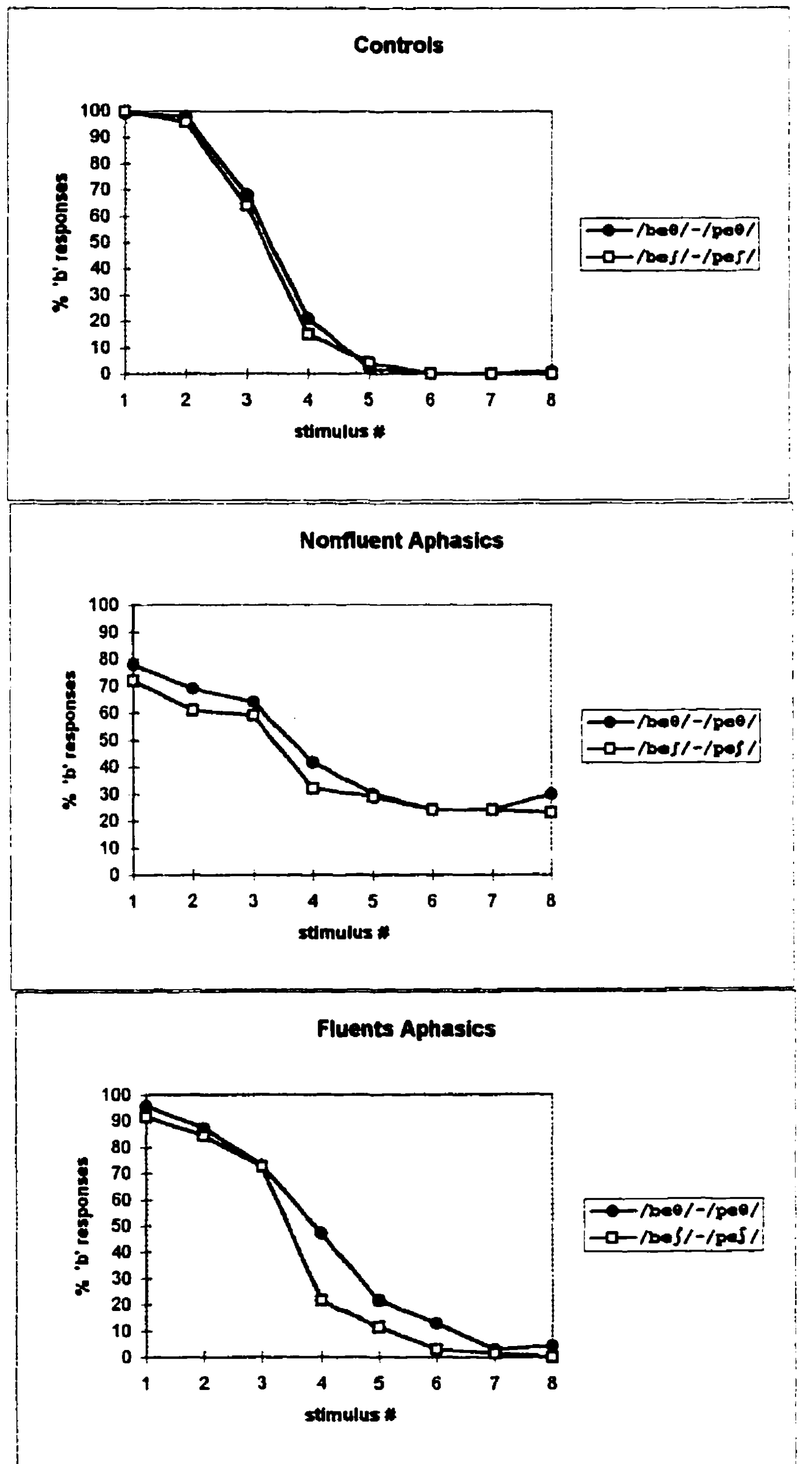


Table 10.
Overall Category Boundaries and Percentage of 'b' Responses

		/beθ/-/peθ/		/beʃ/-/peʃ/	
Controls		Stimulus #	% 'b' Responses	Stimulus #	% 'b' Responses
	1	4.29	46.25	4.07	45.00
	2	3.71	41.25	2.43	23.75
	3	2.25	22.50	2.43	23.75
	4	3.07	33.75	2.80	27.50
	5	3.00	31.25	3.50	37.50
	6	3.50	38.75	3.50	37.50
	7	3.87	41.25	3.37	37.50
	8	2.73	26.25	3.20	35.00
	9	3.29	33.75	3.29	33.75
	10	4.13	46.25	4.34	47.50
	mean	3.38	36.12	3.29	34.87
Nonfluent Aphasics					
	1	3.86	43.04	*	42.50
	2	*	53.75	*	41.25
	3	3.82	43.75	4.00	46.25
	4	*	56.25	*	51.25
	5	*	31.25	*	27.50
	6	3.96	42.50	3.43	37.50
	7	4.36	48.75	*	31.25
	8	3.57	37.50	3.87	42.50
	9	*	41.25	*	46.25
	10	4.94	46.25	3.47	36.25
	mean	4.07	44.43	3.69	40.25
Fluent Aphasics					
	1	3.57	40.00	3.43	35.00
	2	3.86	41.25	2.07	21.25
	3	2.59	28.75	2.74	26.58
	4	5.50	60.76	2.94	30.38
	5	4.20	45.00	4.58	52.50
	6	3.51	38.75	4.00	42.50
	7	5.50	46.25	3.87	41.25
	mean	4.10	42.97	3.38	35.64

*category boundary could not be computed

nonfluent aphasics produced identification functions for one or both continua that did not permit the calculation of boundary values, thus the overall means for this group should be interpreted with caution (examples of these functions are displayed in Figure 6). The control group had a relatively small average boundary shift of 0.09 steps; nonfluent aphasics showed a larger shift of 0.38, and fluent aphasics had the greatest shift at 0.72 steps. All of these boundary shifts were in the direction of a neighborhood effect with higher boundary values for the /beθ/-/peθ/ continuum than the /beʃ/-/peʃ/ continuum. Table 11 displays the VOT values that correspond to the individual subjects' category boundaries. Control subjects had a very small shift of 0.73 msec. This contrasted with larger shifts for the nonfluent (3.30 msec) and fluent (5.80 msec) aphasic groups. As in Experiment 1, the boundary values correspond with those typical of labial stops in English, but at slightly shorter VOT values.

Figure 7 displays the within-group differences in percentage of voiced ("b") responses to the two continua. As with the category boundaries, the control group shows a relatively small difference, averaging 1.25% more "b" responses for the /beθ/-/peθ/ continuum than the /beʃ/-/peʃ/ continuum. The aphasic groups show larger differences of 4.18% for the nonfluents and 7.33% for the fluents (in all cases showing a tendency toward a neighborhood effect).

To determine if any of the above differences reached significance, separate two-way repeated-measures ANOVAs (Group x Continuum) were conducted on transformed boundary values and percentage of "b" responses (see Experiment 1). Because fewer than 5 nonfluent aphasic subjects had

Figure 6.
Functions for which Category Boundaries Could Not Be Computed

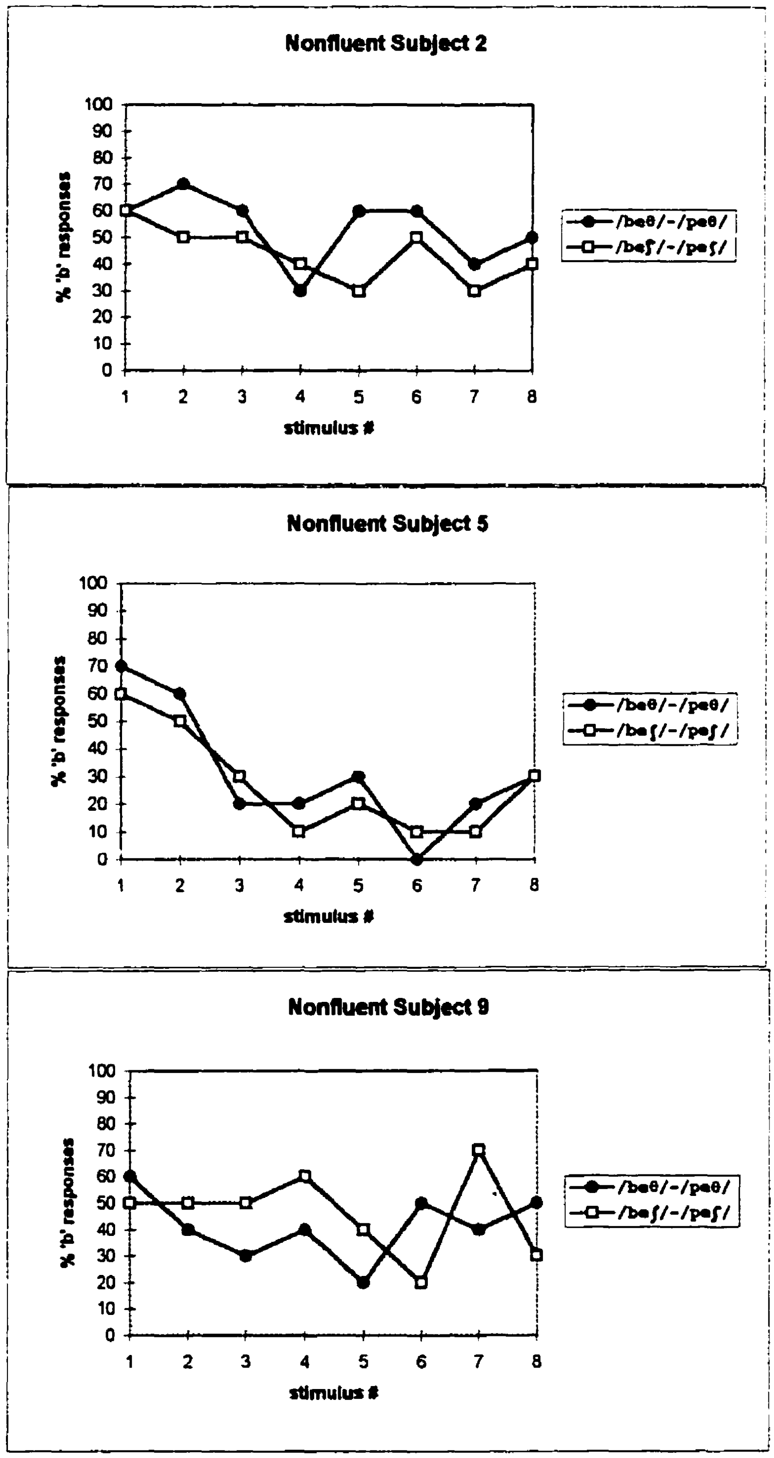
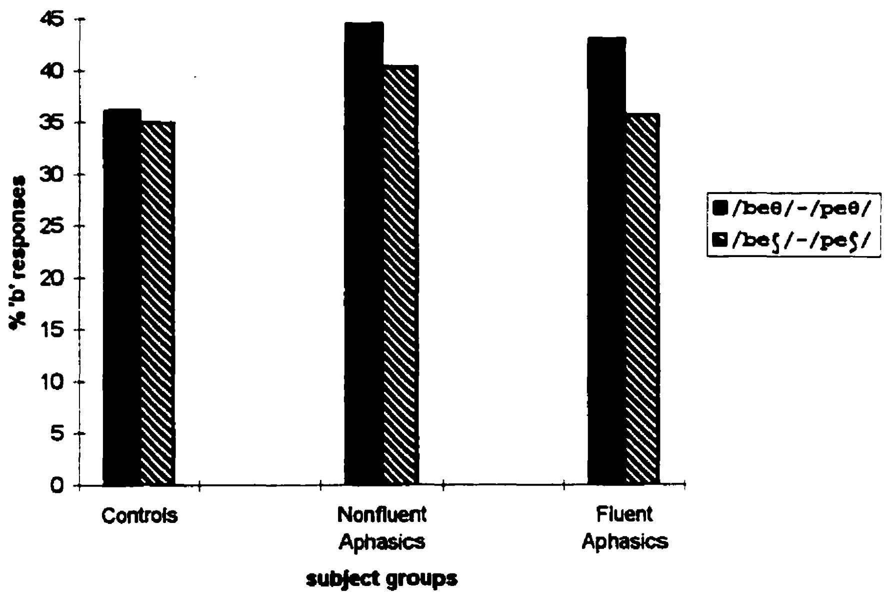


Table 11.
VOT Phonetic Boundaries (in msec)

		/beθ/-/peθ/	/beʃ/-/peʃ/
Controls			
1		33.83	32.10
2		29.17	18.96
3		17.57	18.96
4		23.92	21.81
5		23.35	27.45
6		27.45	27.45
7		30.48	26.38
8		21.27	24.99
9		25.73	25.73
10		32.57	34.22
	mean	26.53	25.80
Nonfluent Aphasics			
1		30.40	*
2		*	*
3		30.07	31.55
4		*	*
5		*	*
6		31.22	26.88
7		34.38	*
8		28.02	30.48
9		*	*
10		38.93	27.20
	mean	32.06	29.03
Fluent Aphasics			
1		28.02	26.88
2		30.40	16.19
3		20.19	21.35
4		43.40	22.89
5		33.12	36.10
6		27.53	31.55
7		43.40	30.48
	mean	32.29	26.49

*phonetic boundary could not be computed

Figure 7.
Percentage of 'b' Responses to the Two Test Continua



identification functions in both continua that were suitable for the calculation of boundary values, this subject group was not included in the category boundary ANOVA. Analysis revealed a main effect of Continuum for percentage of "b" responses ($F(1,24) = 5.519$, $p < 0.03$) and a trend toward an effect of Continuum for category boundaries ($F(1,15) = 3.281$, $p=0.09$). No other effects or interactions were significant.

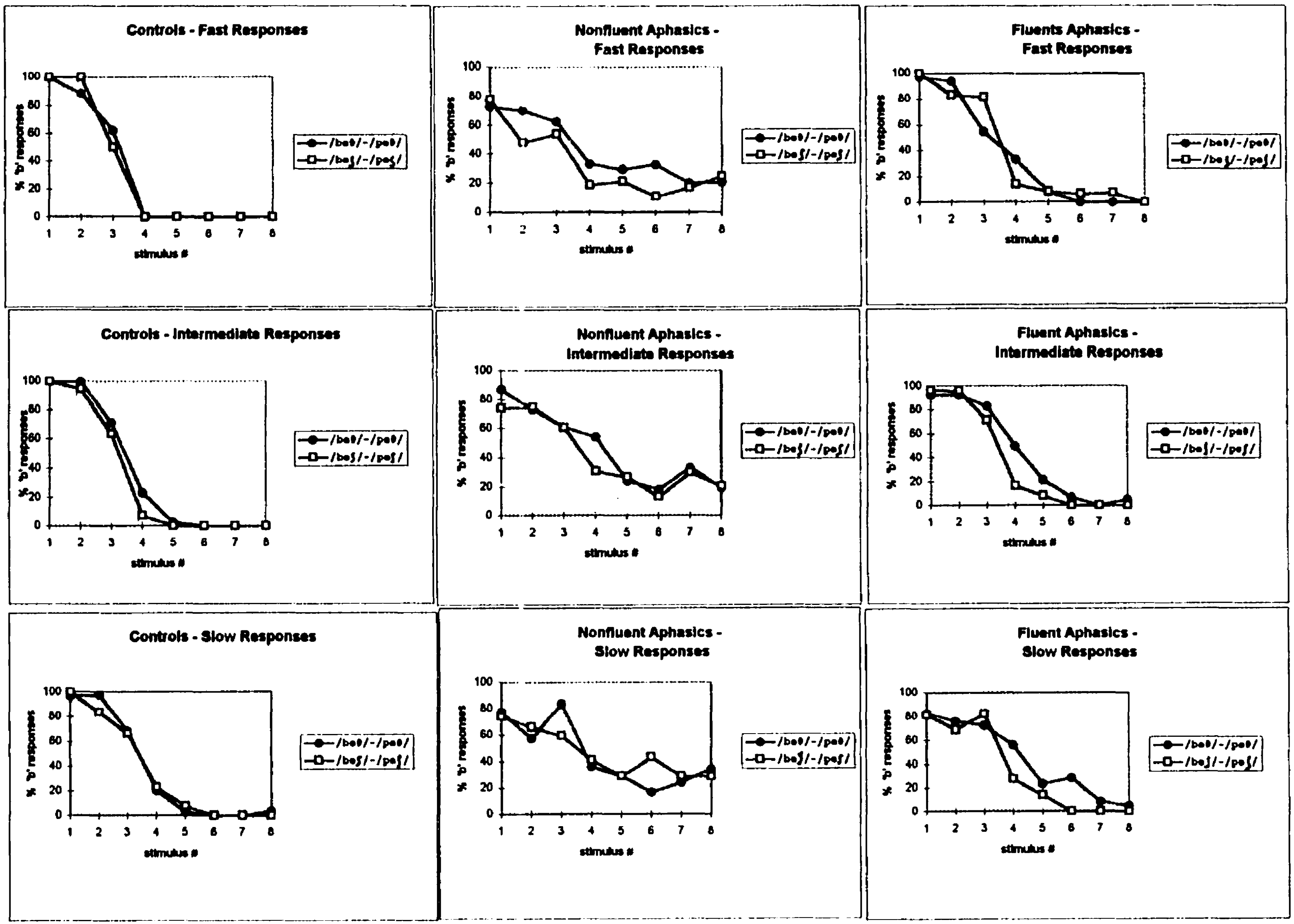
As in Experiment 1, response data were then partitioned into fast, intermediate and slow RT ranges. Table 12 displays the average RT range values for each group of subjects for both continua.

Table 12.
<u>Average Reaction Time Ranges (in msec)</u>

		/beθ/-/peθ/	/beʃ/-/peʃ/
Controls	FAST	525-718	486-733
	INTERMEDIATE	719-871	734-890
	SLOW	>871	>890
Nonfluent Aphasics	FAST	655-1050	543-988
	INTERMEDIATE	1051-1425	989-1453
	SLOW	>1425	>1453
Fluent Aphasics	FAST	564-998	625-980
	INTERMEDIATE	999-1281	981-1304
	SLOW	>1281	>1304

Mean identification functions for all subject groups for the three response ranges are illustrated in Figure 8. The figure reveals that the control subjects show a tendency towards a neighborhood effect that is limited to the

Figure 8.
Mean Identification Functions for Fast, Intermediate, and Slow Response Ranges



intermediate RT range. Fluent aphasics, on the other hand, display an apparent neighborhood tendency in both the intermediate and slow RT ranges. The nonfluent aphasics once again show less steep identification functions, with the possibility of a neighborhood effect in the fast range. It should be borne in mind, however, that the identification functions for the nonfluent aphasic patients were based on fewer data points (as described below).

Tables 13, 14 and 15 display the individual and average boundary values and percentage of "b" responses for the three RT ranges. As is apparent from the tables, many boundaries for the nonfluent aphasics could not be computed. To determine if neighborhood density had an effect on the categorization of phonemes, separate two-way (Group x Continuum) ANOVAs were run on transformed category boundaries and percentage of "b" response values for each RT range. As in the overall category boundary analysis, the nonfluent aphasic group was excluded from statistical analysis in the fast and slow RT ranges due to the small number of subjects for whom boundary values could be calculated for both continua. In addition, control subject 5 was excluded from the analysis of percentage of "b" responses in the fast RT range since she showed no voiced responses for the /beθ/ - /peθ/ continuum (see Table 13). Analysis of the fast RT range produced a significant Group x Continuum interaction for percentage of "b" responses ($F(2,24) = 7.827$, $p < .003$). Post-hoc Newman-Keuls comparisons ($p < .05$) revealed that nonfluent aphasic subjects showed a significantly greater number of voiced responses for the /beθ/ - /peθ/ continuum than the /beʃ/-/peʃ/ continuum, indicating a

Table 13.
Category Boundaries and Percentage of 'b' Responses for Fast RT Range

	/beθ/-/peθ/		/beʃ/-/peʃ/	
	Stimulus #	% 'b' Responses	Stimulus #	% 'b' Responses
Controls				
1	4.00	44.44	4.00	59.26
2	3.50	51.85	2.50	51.85
3	1.50	7.41	2.00	14.81
4	3.00	35.71	2.50	48.15
5	*	0.00	3.50	33.33
6	3.50	22.22	3.00	22.22
7	3.50	48.15	3.50	59.26
8	2.50	14.81	3.00	28.57
9	3.00	28.57	3.00	59.26
10	4.00	28.57	3.50	14.81
mean	3.17	31.30	3.05	39.80
Nonfluent Aphasics				
1	3.99	48.15	*	29.63
2	*	51.85	*	48.15
3	5.21	51.85	*	55.55
4	*	59.26	3.74	37.04
5	*	33.33	*	14.81
6	3.50	44.44	3.50	51.85
7	4.67	62.96	*	32.14
8	3.08	51.85	3.50	37.04
9	*	25.93	*	22.22
10	3.76	48.15	1.07	11.11
mean	3.45	47.78	2.69	33.95
Fluent Aphasics				
1	4.50	37.04	3.50	44.44
2	2.61	29.63	1.88	7.41
3	2.50	33.33	2.57	25.93
4	4.51	62.96	3.50	48.15
5	4.00	40.74	5.00	57.14
6	3.59	59.26	4.53	55.55
7	3.00	45.83	3.50	51.85
mean	3.53	44.11	3.50	41.50

* category boundary could not be computed

Note: Control Subject 5 was not included in the calculation of the group means

Table 14.
Category Boundaries and Percentage of 'b' Responses for Intermediate RT Range

	/beθ/-/peθ/		/beʃ/-/peʃ/	
	Stimulus #	% 'b' Responses	Stimulus #	% 'b' Responses
Controls				
1	3.50	40.74	4.00	29.63
2	4.50	44.44	2.50	29.63
3	2.50	25.93	2.00	14.81
4	3.87	34.62	2.50	14.81
5	3.00	40.74	3.50	35.71
6	3.00	39.29	3.50	25.93
7	3.89	37.04	3.17	25.93
8	2.50	14.81	3.50	38.46
9	3.00	23.08	3.00	14.81
10	4.50	61.54	4.11	66.67
mean	3.43	36.22	3.18	29.64
Nonfluent Aphasics				
1	4.29	50.00	*	29.63
2	*	55.55	4.27	33.33
3	4.98	51.85	1.16	33.33
4	*	66.66	*	66.66
5	*	22.22	2.30	29.63
6	3.35	37.04	3.11	33.33
7	4.17	53.57	3.00	26.92
8	3.50	37.04	3.50	37.04
9	*	51.85	*	51.85
10	3.80	44.44	4.10	37.04
mean	3.96	47.02	2.97	37.88
Fluent Aphasics				
1	3.50	37.04	3.50	22.22
2	4.92	48.15	2.32	14.81
3	*	22.22	2.71	25.93
4	5.50	59.26	3.25	7.41
5	4.00	44.44	4.50	34.62
6	4.00	33.33	3.33	29.63
7	3.89	40.74	4.00	25.93
mean	4.30	40.74	3.48	22.94

*category boundary could not be computed

Table 15.
Category Boundaries and Percentage of 'b' Responses for Slow RT Range

	/beθ/-/peθ/		/beʃ/-/peʃ/	
	Stimulus #	% 'b' Responses	Stimulus #	% 'b' Responses
Controls				
1	4.44	53.85	4.16	46.15
2	3.33	26.92	1.82	7.69
3	2.31	36.00	2.55	42.31
4	3.00	30.77	2.86	19.23
5	3.04	50.00	3.50	44.00
6	2.58	56.00	3.86	65.38
7	3.89	38.46	3.76	26.92
8	2.83	50.00	3.17	38.46
9	3.30	50.00	3.14	26.92
10	4.08	50.00	4.78	61.54
mean	3.28	44.20	3.36	37.86
Nonfluent Aphasics				
1	*	30.77	*	69.23
2	*	53.85	*	44.00
3	3.33	26.92	3.89	50.00
4	*	42.31	*	50.00
5	*	38.46	*	38.46
6	*	46.15	3.42	26.92
7	4.39	28.00	*	34.62
8	3.86	23.08	4.62	53.85
9	*	46.15	*	65.30
10	4.79	48.00	3.31	61.54
mean	3.99	38.37	3.94	49.39
Fluent Aphasics				
	4.07	46.15	2.90	40.74
	4.03	46.15	2.69	42.31
	*	30.77	3.15	28.00
	5.65	60.00	2.40	36.00
	4.60	50.00	4.57	65.38
	*	23.08	3.50	42.31
	4.50	57.69	4.17	46.15
mean	4.57	44.83	3.35	42.98

*category boundary could not be computed

neighborhood density effect. Neither the normal or fluent aphasic groups showed a significant difference.

Analysis of the intermediate response range revealed a main effect of Continuum for both category boundaries ($F(1,18) = 5.450$, $p < .04$) and percentage of "b" responses ($F(1,24) = 16.342$, $p < .001$). Both of these results were in the direction of a neighborhood effect, with higher boundary values and a greater number of "b" responses to the /beθ/-/peθ/ continuum as compared to the /beʃ/-/peʃ/ continuum. There was also a trend toward an effect of Group ($F(2,24) = 2.643$, $p = 0.092$) with the aphasic subject groups tending to show higher boundary values than the normal controls.

Category boundary values in the slow RT range revealed a trend toward an effect of Continuum ($F(1,13) = 4.351$, $p = .057$) and a significant Group x Continuum interaction ($F(1,13) = 4.944$, $p < .05$). As noted above, analysis of category boundaries in this range included only (10) normal and (5) fluent aphasic subjects. Post-hoc Newman-Keuls comparisons showed that the differences in boundary values for fluent aphasics fell just short of significance, whereas the normal control group showed no evidence of a neighborhood density effect. The Group x Continuum interaction for boundary values was supported by a significant Group x Continuum interaction for percentage of "b" responses ($F(1,13) = 4.944$, $p = .05$). However, Newman-Keuls comparisons showed no significant differences between groups. No significant effects emerged in the analysis of percentage of voiced responses in this range, most likely due to the inconsistency in response pattern, particularly within the nonfluent aphasic group (see Table 15).

Discussion

The present experiment provides support for the theory that, upon presentation of an auditory stimulus, a group of similar-sounding phonetic patterns are activated in a listener's lexicon (eg. Luce, 1986; Luce et al., 1990). Further, it seems that the collective activation level of this group of phonological "neighbors" may influence the identification of individual phonetic segments that are perceptually ambiguous, causing listeners to categorize these segments as the phoneme corresponding to a larger, or more active, lexical neighborhood (Newman et al., in press). This finding has important implications for previous studies which have shown lexical effects in phoneme identification tasks (Burton et al., 1989; Connine & Clifton, 1987; Fox, 1984; Ganong, 1980; Pitt & Samuel, 1993). The present results, together with Newman et al.'s (in press) findings, suggest that neighborhood density is a factor that must be controlled when employing word-nonword continua in these types of tasks.

Prior to discussing the effects of neighborhood density in greater detail, one other important finding should be mentioned. As was evident in Table 10, category boundaries for many aphasic subjects could not be calculated in the individual RT ranges. This was particularly true for the nonfluent aphasics and was due to irregular identification functions which showed no clear crossover point in perception along the /b/ - /p/ VOT continua. While there were also several aphasic subjects in Experiment 1 who exhibited similar difficulty in making phonetic judgements, this problem seemed much more prevalent in the present experiment. The greater difficulty in making phonetic identifications in Experiment 2 may be accounted for by a comparison of the stimuli employed in each experiment. One of the goals of Experiment 1 was to investigate the conditions under which a lexical effect might emerge. To this end, each VOT continuum was constructed so that one endpoint formed a word and the other resulted in a nonword. Thus, roughly half of the stimulus set that subjects listened to sounded like words. The present experiment, which was strictly searching for neighborhood effects, utilized only nonword endpoints on the VOT continua. It has been previously noted that many aphasic patients tend to display more difficulty in making phonetic discriminations in nonwords than in words (Blumstein et al., 1977). Thus, it is possible that lacking a lexical referent to aid their phonetic judgements, aphasic subjects resorted to guessing-type behaviour in Experiment 2. In addition, Gow and Caplan (1996) noted that phoneme identification tasks "using nonsense stimuli are frequently described by subjects as being tedious and unengaging" (p.389). Perhaps a general lack of attention to the task in this experiment may also have contributed to less stable identification functions for aphasic subjects.

Returning to the primary concern of the present experiment, the major finding was a significant effect of neighborhood density across subject groups in both the overall data and the intermediate RT range. In the overall data, the neighborhood influence was reflected in a main effect of Continuum for percentage of "b" responses, and supported by a trend toward an effect of Continuum in terms of category boundaries. The intermediate RT range, in particular, showed even stronger effects of neighborhood density for both percentage of "b" responses and category boundaries. The appearance and size of these effects were in accord with the results of Newman et al.'s (in press) study with young normals, which showed a small overall effect of neighborhood density, and a more robust effect in the intermediate RT range. Although no significant Group x Continuum interaction emerged in the overall data, it appears that the greatest contribution to an effect of neighborhood density came from the aphasic subject groups. This is reflected in greater shifts in the phonetic identification functions for these groups (as seen in Figure 5), as well as greater differences in percentage of "b" responses to the two continua (Figure 7). The small shift in the control group function is similar to the pattern displayed by young normals in Newman et al.'s study.

While it was hypothesized that nonfluent aphasics would show a significantly greater overall effect of neighborhood density than both the normal and fluent aphasic groups (based on the findings of Experiment 1; see also Blumstein et al., 1994), such a finding did not emerge. Although analysis of the overall data revealed no group differences in the size of the neighborhood effect, analysis of individual RT ranges were suggestive of potential differences across groups. In particular, within the fast RT range, the nonfluent aphasic patients showed a neighborhood effect that was not apparent in the normal or fluent aphasic subject groups, suggesting increased influence of neighborhood density for these patients. However, this finding must be interpreted with caution due to the small number of responses for each subject in each RT range. Further, the difference in neighborhood density effects that did emerge in the fast RT range was based only on the percentage of "b" responses to the two continua; statistics on category boundaries for this range could not be computed due to a large number of missing values for the nonfluent aphasic group. Still, the mean identification functions of the nonfluent aphasics in the fast range (Figure 8) show them to be the only group displaying a clear and consistent influence of neighborhood density across the phonetic identification continua. A more thorough treatment of the possible time course of neighborhood activation for both normal and aphasic subjects will be addressed in the General Discussion.

The performance of the fluent aphasic group in this experiment produced some unexpected results. Considering the overall data, the fluent aphasic subjects appeared to be the most susceptible to an influence of neighborhood density. This was evident both in terms of boundary values and percentage of "b" responses. Likewise, their mean identification functions in the intermediate and slow RT ranges (Figure 8) seem to reveal larger shifts than both normals and nonfluent aphasics, although no significant Group x Continuum interaction emerged. These results are not consistent with Blumstein et al.'s (1994) suggestion that fluent aphasics are unable to utilize lexical strategies in making phonetic categorizations. As was mentioned in the discussion of Experiment 1, Blumstein et al.'s study and the present investigation differ in both the type of stimuli employed and the characteristics of the aphasic patient groups -- both of which may have contributed to the differing results. Further, it should be borne in mind that a lexical effect would not necessarily be tapping the same processes as a neighborhood effect. While the lexical effect is supposedly the product of the activation a single word in the mental lexicon, neighborhood effects reflect sensitivity to more general levels of activation that are the products of groups of lexical items (Newman et al., 1994). Results from several previous studies have suggested that fluent aphasics have a lower threshold for accessing the lexicon, with the result that upon hearing a stimulus, a greater number of phonetically similar lexical patterns are activated in these patient's lexicons, as compared to normals or Broca's aphasics (Blumstein et al., 1982; Leonard & Baum, in press; Milberg et al., 1988b). Thus, it is possible that neighborhood density, which is a measure of general levels of lexical activation, may exert a bigger influence for the fluent aphasics who tend to "overactivate" the lexicon.

In sum, it appears that phonological neighborhoods of nonword endpoints on a phonetic identification continuum may play a role in the categorization of phonemes for both elderly normal and aphasic subjects. Although the role of neighborhood density with word endpoints was not directly investigated in this experiment, there are no intuitive reasons why the phonological neighborhoods of these stimuli would not also play a role in phonetic categorization. The implications of these findings for the interpretation of previous investigations of the lexical effect with both normal and aphasic subjects will be addressed in the General Discussion.

General Discussion

The combined results of Experiment 1 and Experiment 2 indicate that lexically-based sources of information may influence the identification of phonemes in both normal and aphasic subjects. This influence seems to be the strongest in cases where listeners are uncertain about their acoustic-phonetic judgements, causing them to rely on higher-level linguistic information to guide a phonetic decision (cf. Burton et al., 1989; Ganong, 1980). Furthermore, Experiment 2 supports Newman et al.'s (in press) contention that phonological neighborhoods of words and nonwords are a relevant factor in phonetic identification tasks, and may bias the perception of phonetic segments in a manner that parallels the lexical effect.

Beyond determining the contribution of neighborhood density to phonetic identification, the present study sought to outline the possible time course of this effect, and when it might occur in relation to a lexical influence. Luce et al. (1990) have previously suggested that the activation of phonological neighbors is an event which precedes word recognition. Thus, as Newman et al. (in press) noted, a neighborhood effect on phonetic identification might also be expected to precede a lexical influence, since the collective activation level of any particular word's neighborhood is higher before that word is recognized. The combined results of Experiment 1 and Experiment 2 are inconsistent with this hypothesis. While an overall lexical effect emerged in Experiment 1, and an overall neighborhood effect emerged in Experiment 2, analysis of RT range data indicated that the lexical effect occurred primarily for fast responses while the neighborhood effect was most dominant in the intermediate RT range. The emergence of a lexical influence exclusively in the fast range is especially surprising, since the lexical effect has never been reported in one RT range and not in all others that are slower (see Pitt & Samuel, 1993). Nevertheless, it should still be noted that the present study differed from these previous reports in that analyses here included data from both elderly normal and fluent and nonfluent aphasic patients. Not surprisingly, the individual RT ranges established for these subjects were highly variable in terms of both size and absolute time boundaries. A fairer evaluation of the RT range results for the lexical and neighborhood effects may be undertaken by considering the response patterns of the individual subject groups within each range.

As was evident in Figure 4 (Experiment 1), the elderly control group showed identification functions in all 3 RT ranges that were consistent with an influence of lexical status. Although the lexical effect more commonly shows up in intermediate and slow RT ranges (Burton et al., 1989; Fox, 1984; Miller & Dexter, 1988), some previous studies have also displayed evidence of a lexical effect through all RT ranges (Burton & Blumstein, 1995; Pitt & Samuel, 1993). Further, the slower response times displayed by elderly normals and aphasic subjects in the present study may also make a lexical effect in the fast range seem even less surprising, since slower responses may conceivably allow more time for lexical information to bias phonetic judgements.

The primary reason for the absence of a significant lexical effect emerging in the statistical analysis of the intermediate and slow RT ranges of

Experiment 1 was largely due to the performance of the aphasic subject groups. Hagoort (1993) has previously suggested that the activation levels of lexical items decay more rapidly for aphasic subjects as compared to normal subjects. Thus, it is possible that the activation of word endpoints in Experiment 1 was only strong enough in the fast range to influence the fluent and nonfluent aphasic subjects' phonetic judgements but had decayed by the intermediate and slow RT ranges. While this is one possible reason for these unexpected results, perhaps an even stronger factor in the lack of a lexical effect for the slower RT ranges may be the phonological neighborhoods of endpoint stimuli. It will be recalled that appropriate endpoints for word-nonword and nonword-word continua in Experiment 1 could not be found that were equal in neighborhood density. Thus, it was ensured that the nonword continua endpoints had the greater neighborhood density value so that this type of influence in no way contributed to any lexical effect. This created two potentially conflicting biases in Experiment 1, with lexical and neighborhood effects working in opposing directions. Although the lexical effect still emerged in the overall and fast RT range data, it is possible that neighborhood effects were strongest for intermediate and slow responses, essentially counteracting lexical effects in these ranges. In fact, this appeared to be the case in Experiment 2, which showed strong of effects of neighborhood density in the intermediate RT range across groups, and a trend towards a neighborhood influence in the slow range. Thus, the pattern of results for the RT range data in Experiment 2 seem to suggest that an influence of neighborhood density that emerges in intermediate and slow responses may have mitigated a lexical effect in these ranges in Experiment 1.

The response patterns for Experiment 2 (which was strictly examining the influence of neighborhood density) are essentially in line with those found in Newman et al.'s (1996) study which utilized the same stimuli and found a small effect of neighborhood density overall, with the greatest influence occurring in the intermediate RT range. In the present study, the nonfluent aphasic group showed a significant influence of neighborhood density only in the fast RT range. This, in some sense, is in agreement with the proposal that nonfluent Broca's aphasic patients may show a weakened spread of activation among lexical candidates (Blumstein et al., 1982; Leonard & Baum, in press; Milberg et al., 1988b). That is, it is possible that what has previously been interpreted as a deficit in the automatic spread of activation may rather be a more rapid decay in the activation levels of related lexical items in nonfluent aphasics as compared to normals (cf. Hagoort, 1993). The current study, which examines the response patterns of subjects by reaction time range, may be able to tap the rates of activation and inhibition of lexically-related items more clearly than lexical decision studies which use reaction time as a dependent variable. Thus, it is possible that relatively transient lexical activity in nonfluent aphasic patients may have been erroneously interpreted in previous studies as a lack of automatic spread of activation amongst lexical items.

Contrary to the proposed impairment in automatic spread of activation for Broca's patients, deficits observed in lexical access in fluent Wernicke's aphasia have often been attributed to an overactivation of lexical candidates (Blumstein et al., 1982; Milberg et al., 1988b). The assumption of an automatic spread of activation amongst phonologically-related lexical items is central to both the neighborhood activation model of word recognition (Luce, 1987; Luce et al., 1990) and the process upon which effects of neighborhood density in the present phonetic identification tasks depend. The identification functions for fluent aphasic patients, which show a neighborhood influence in the intermediate and slow RT ranges, along with their overall greater susceptibility to the influence of neighborhood density in making phonetic identifications (as seen in Figure 7), is in accord with this overactivation hypothesis.

In summary, analysis of the RT range results for both experiments have not supported the conclusion that neighborhood and lexical effects are sequential in phonetic identification. If, instead, these two lexical influences are simultaneous, this would account for the surprising emergence of the lexical effect exclusively in the fast range in Experiment 1. Stronger co-occurring influences of neighborhood density in intermediate and slow RT ranges (similar to results in Experiment 2) may have cancelled out lexical effects in these RT ranges. Still, if a neighborhood influence is operating in both the intermediate and slow ranges in Experiment 1 (and possibly, to a lesser extent, in the fast range), this is inconsistent with Luce et al.'s (1990) proposal that the activation levels of lexical-phonological neighborhoods are quickly attenuated after hearing a phonetic pattern. While this type of inhibition seems like a necessary process in order for word recognition to take place, it is not as readily apparent why the same rapid decay or inhibition of neighbors might occur when listeners are presented with a nonword. In these situations, it seems possible that the initially activated group of phonetic patterns may remain active for a longer period of time while a listener continues to search for a non-existent lexical item. Previous research has shown that subjects are able to make lexical decisions more quickly for words as opposed to nonwords (Rubenstein, Garfield, & Milkan, 1970). If neighborhoods remain active longer when nonwords are presented, it is not surprising that Experiment 2 revealed a neighborhood effect in the intermediate RT range and a trend toward an effect of neighborhood in the slow range. These interpretations must remain speculative, however, as the RT range results for both the neighborhood and lexical effect were based on a relatively small number of responses in each RT range for individual subjects. Further research with larger sample sizes and a larger number of stimuli must be conducted in order to more precisely chart the time course of both the lexical and neighborhood effects in elderly normal and aphasic subjects.

One of the goals of the present study was to investigate the possibility that nonfluent aphasics place a greater dependence upon higher-level linguistic influences in identifying phonemes than normal subjects or fluent aphasics, as suggested by Blumstein et al. (1994). This contention was partially supported by the results of Experiment 2, which showed greater overall differences in percentage of voiced responses (suggesting a neighborhood effect) for the aphasic groups, as well as a significant effect of neighborhood density for nonfluent aphasics in the fast RT range which was not evident in the other subject groups. While evidence of a greater influence of lexical status for nonfluent aphasics did not emerge in Experiment 1, it is possible that, as suggested above, a co-occuring influence of neighborhood density was greater for aphasic patients as compared to normals. This may have masked a greater susceptibility to lexical influences for one or both groups of aphasic subjects. It is also worth mentioning that Blumstein et al. (1994) did not control the neighborhood density values of their continua endpoints. Thus, it is not clear in what way this factor may have contributed to (or detracted from) a lexical effect in their study. Furthermore, as is well known, there is a great deal of heterogeneity within aphasic subject groups classified according to syndromes and/or fluency (see Caramazza, 1984; Schwartz, 1984). Perhaps in future investigations of lexical or neighborhood density effects on phonetic perception, it would be useful to group patients according to phonetic discrimination abilities, regardless of syndrome, to determine how lexical influences may affect phonetic identification.

One of the primary motivations for research into lexical influences in phonetic identification has been to address the question of whether the process of word recognition proceeds in a bottom-up manner, with autonomous stages of phonetic and lexical processing, or results from interactivity among various components of the language processing system. While we did not set out to address these broad theoretical views of language processing (or any specific models of word recognition), the results of the current investigation are most consistent with an interactive view of speech perception, such as that proposed in the TRACE model (Elman & McClelland, 1986; McClelland & Elman, 1986). Earlier investigations have suggested that top-down (lexical) influences on phonetic identification may be post-perceptual or may emerge only in cases of great uncertainty (Burton et al., 1989). In the present study, there was no clear demarcation of the time course for either the neighborhood or lexical effect, with the fast RT range in both experiments showing (for one or more subject groups) a top-down influence on phonetic identification. These findings render questionable the argument that lexical effects are post-perceptual, as proposed by Fox (1984; see also Burton et al., 1989; McQueen, 1991). Still, caution must be exercised in drawing any conclusions regarding the interactivity versus autonomy debate. As already mentioned, the number of responses for each subjects' individual RT ranges were relatively small. Furthermore, the identification functions for aphasic patients show that lexical influences may emerge at any point along the continua, demonstrating that these influences occur when, for whatever reason, acoustic-phonetic information is unclear to the listener. Such a finding seems to be consistent with Burton et al.'s (1989) proposal which suggests that lexical influences occur after low-level acoustic-phonetic analyses have failed (supporting a more autonomous view of language processing). In any case, attempting to analyze the time course of lexically-based influences on phonetic perception with elderly normal and aphasic patients is especially difficult, due to a lack of certainty over what components of language processing may be slowed by aging (Klatzky, 1988; Salthouse, 1988), and what the nature of the underlying deficits are within different aphasia syndromes. Thus, further research is needed to determine the time course of lexical and neighborhood effects with both normal and brain-damaged populations, and to examine what these effects reveal about claims of autonomy, or interaction, in language processing.

It is noteworthy that the findings of the present study are consistent with the basic claims of the Neighborhood Activation Model (NAM) of word recognition (Luce, 1986; Luce et al., 1990). The significant effects of neighborhood density that emerged in Experiment 2 demonstrated that groups of similar phonetic patterns are activated in the mental lexicon upon hearing an auditory stimulus, whether it be a word or a nonword, consistent with NAM.

In conclusion, the findings of the present study support the contention that phonological neighborhoods are a relevant factor in phonetic identification studies employing word and nonword stimuli. While Pitt and Samuel (1993) revealed several sources of variation in studies that have examined the lexical influence on phonetic identification, the present investigation demonstrated that neighborhood density is also an important factor to control in the design of phonetic identification continua (see also Newman et al., in press). The emergence of neighborhood density effects for aphasic patients also provides support for the contention that lexical access deficits in these subjects are not the product of a disturbance in the lexical base of information, but result from deficits in the processes involved in retrieving and acting upon this information (Hagoort, 1993; Milberg et al., 1987). While previous research has suggested that nonfluent aphasics may show a greater reliance on heuristic strategies in language processing than fluent aphasics or normals (Blumstein et al., 1991; Blumstein et al., 1994; Milberg et al., 1995), the results of the current study are somewhat ambiguous in terms of the relative dependencies of aphasic subjects on higher-level sources of information in phonetic processing. The combined results of the two experiments suggest that both fluent and nonfluent patients are able to use lexically-based strategies to guide their phonetic judgements when experiencing stimulus uncertainty. Future research must seek to more clearly define the time-course of neighborhood and lexical effects on phonetic identification both for these patients and normal subjects.

Footnotes

[1] The density value (number of neighbors) and mean log of neighborhood frequency for each word and nonword were provided by Paul Luce.

REFERENCES

Andruski, J. E., Blumstein, S. E., & Burton, M. (1994). The effect of subphonetic differences on lexical access. Cognition, 52, 163-187.

Aydelott-Utman, J. & Blumstein, S. E. (1995). On the nature of lexical processing in Broca's aphasia: Effects of subphonetic acoustic differences on lexical access. Paper presented at The Academy of Aphasia, 33rd Annual Meeting, San Diego, California, November, 1995.

Baker, E., Blumstein, S. E., & Goodglass, H. (1981). Interaction between phonological and semantic factors in auditory comprehension. Neuropsychologia, 19, 1-16.

Bergman, M., Blumenfeld, V. G., Cascardo, D., Dash, B. Levitt, H., & Margulies, M. K. (1978). Age-related decrement in hearing for speech: Sampling and longitudinal studies. Journal of Gerontology, 31, 533-538.

Basso, A., Casati, G., & Vignolo, L. A. (1977). Phonemic identification defects in aphasia. Cortex, 13, 84-95.

Blank, M. A., & Foss, D. J. (1978). Semantic facilitation and lexical access during sentence processing. Memory & Cognition, 6, 644-652.

Blumstein, S. E., (1991). Phonological aspects of aphasia. In M.T. Sarno (ed.) Acquired Aphasia. New York: Academic Press.

Blumstein, S. E., Baker, E., & Goodglass, H. (1977). Phonological factors in auditory comprehension in aphasia. Neuropsychologia, 15, 19-30.

Blumstein, S. E., Burton, M., Baum, S., Waldstein, R., & Katz, D. (1994). The role of lexical status on the phonetic categorization of speech in aphasia. Brain and Language, 46, 181-197.

Blumstein, S.E., Cooper, W. E., Zurif, E. B., & Caramazza, A. (1977). The perception and production of voice onset time in aphasia. Neuropsychologia, 15, 371-383.

Blumstein, S. E., Katz, B., Goodglass, H., & Dworetzky, B. (1985). The effects of slowed speech on auditory comprehension in aphasia. Brain and Language, 24, 246-265.

Blumstein, S. E., Milberg, W., Dworetzky, B., Rosen, A., & Gershberg, F. (1991). Syntactic priming effects in aphasia: An investigation of local syntactic dependencies. Brain and Language, 40, 393-421.

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

Blumstein, S. E., & Stevens, K. N. (1980). Perceptual invariance and onset spectra for stop consonants in different vowel environments. Journal of the Acoustical Society of America, 67, 648-662.

Burton, M. W., Baum, S. R., & Blumstein, S. E. (1989). Lexical effects on the phonetic categorization of speech: The role of acoustic structure. Journal of Experimental Psychology: Human Perception and Performance, 15, 567-575.

Burton, M. W., & Blumstein, S. E. (1995). Lexical effects on phonetic categorization: The role of stimulus naturalness and stimulus quality. Journal of Experimental Psychology: Human Perception and Performance, 21, 1230-1235.

Caplan, D., & Aydelott-Utman, J. (1994). Selective acoustic-phonetic impairment and lexical access in an aphasic patient. Journal of the Acoustical Society of America, 95, 512-517.

Caplan, D., & Bub, D. (1990). Psycholinguistic Assessment of Aphasia. Mini-seminar presented at American Speech and Hearing Association Conference, Seattle, WA.

Caramazza, A. (1984). The logic of neuropsychological research and the problem of patient classification in aphasia. Brain and Language, 21, 9-20.

Cole, R. A. (1973). Listening for mispronunciations: A measure of what we hear during speech. Perception and Psychophysics, 13, 153-156.

Cole, R. A., & Jakimik, J. (1978). Understanding speech: How words are heard. In G. Underwood (Ed.), Strategies of information processing. New York: Academic.

Cole, R. A., Jakimik, J., & Cooper, W. E. (1978). Perceptibility of phonetic features in fluent speech. Journal of the Acoustical Society of America,64, 44-56.

Connine, C. M. (1987). Constraints on interactive processes in auditory word recognition: The role of sentence context. Journal of Memory and Language, 26, 527-538.

Connine, C. M., & Clifton, C. C. Jr., (1987). Interactive use of lexical information in speech perception. Journal of Experimental Psychology: Human Perception & Performance, 13, 291-299.

Elman, J. L. & McClelland, J. L. (1984). The interactive activation model of speech perception. In N. Lass (Ed.), Language and Speech, (pp.337-374). New York: Academic Press.

Elman, J. L. & McClelland, J. L. (1986). Exploiting lawful variability in the speech wave. In J. S. Perkell, & D. H. Klatt (Eds.), Invariance and Variability in Speech Processes (pp.360-380). Hillsdale, NJ: Lawrence Erlbaum.

Forster, K.I. (1976). Accessing the mental lexicon. In R.J. Wales and E. Walker (Eds.), New approaches to language mechanisms (pp. 257-287). Amsterdam: North Holland.

Fox, R. A. (1984). Effect of lexical status on phonetic categorization. Journal of Experimental Psychology: Human Perception and Performance, 10, 526-540.

Ganong, W. F. (1980). Phonetic categorization in auditory word perception. Journal of Experimental Psychology: Human Perception and Performance, 6, 110-125.

Goodglass, H., & Kaplan, E. (1983). The Assessment of Aphasia and Related Disorders. Philidelphia, PA: Lea and Febiger.

Gow, D. Jr., & Caplan, D. (1996). An examination of impaired acoustic-phonetic processing in aphasia. Brain and Language, 52, 386-407.

Grosjean, F. (1980). Spoken word recognition processes and the gating paradigm. Perception and Psychophysics, 28, 267-283.

Grosjean, F. (1985). The recognition of words after their acoustic offset: Evidence and implications. Perception and Psychophysics, 38, 299-310.

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

Jusczyk, P. (1986). Speech perception. In K. R. Boff, L. Kaufman, & J. P. Thomas (Eds.), Handbook of perception and human performance: Vol 2. Cognitive processes and performance, New York: John Wiley & Sons.

Klatzky, R. (1988). Theories of information processing and theories of aging. In Light & Burke (Eds.), Language, memory, and aging. pp. 1-16. Cambridge: Cambridge University Press.

Kucera, H., & Francis, W. N. (1967). A computational analysis of present-day American English. Providence, RI: Brown University Press.

Leonard, C. L., & Baum, S. R. (in press). The influence of phonological and orthographic information on auditory lexical access in brain-damaged patients: A preliminary investigation. Aphasiology.

Liberman, A. M, Cooper, F. S., Shankweiler, D. P., & Studdert-Kennedy, M. (1967). Perception of the speech code. Psychological Review, 74, 431-461.

Lisker, L., & Abramson, A. S. (1964). A cross-language study of voicing in initial stops: Acoustical measurements. Word, 20, 384-422.

Luce, A. R. (1986). Neighborhoods of words in the mental lexicon. Doctoral dissertation, Indiana University, Bloomington, Indiana.

Luce, P., Pisoni, D., & Goldinger, S. (1990). Similarity neighborhoods of spoken words. In G. Altman (Ed.), Cognitive models of speech processing (pp. 122-147). Cambridge, MA: MIT Press.

Luria, A. R., (1947). Traumatic Aphasia. The Hague: Mouton. Reprinted in translation (1970).

Marslen-Wilson, W. D. (1975). Sentence processing as an interactive parallel process. Science, 189, 226-228.

Marslen-Wilson, W. D. (1985). Speed shadowing and speech comprehension. Speech Communication, 4, 55-73.

Marslen-Wilson, W. D. (1987). Functional parallelism in spoken word recognition. Cognition, 25, 71-102.

Marslen-Wilson, W., Moss, H, & Van Halen, S. (1996). Perceptual distance and competition in lexical access. Journal of Experimental Psychology: Human Perception and Performance, 22, 1376-1392.

Marslen-Wilson, W. D., & Tyler, L. K. (1980). The temporal structure of spoken language understanding. Cognition, 1980, 8, 1-71.

Marslen-Wilson, W. D., & Tyler, L. K. (1981). Central processes in speech understanding. Philosophical Transactions of the Royal Society of London, B 295, 317-332.

Marslen-Wilson, W., & Warren, P. (1994). Levels of perceptual representation and process in lexical access: words, phonemes, and features. Psychological Review, 101, 653-675.

Marslen-Wilson, W. D., & Welsh, A. (1978). Processing interactions and lexical access during word recognition in continuous speech. Cognitive Psychology, 10, 29-63.

Marslen-Wilson, W. D., & Zwitserlood, P. (1989). Accessing spoken words: The importance of word onsets. Journal of Experimental Psychology: Human Perception and Performance, 15, 576-585.

Massaro, D.W. (1987). Speech perception by ear and eye: A paradigm for psychological inquiry. Hillsdale, NJ: Lawrence Erlbaum.

Massaro, D. W. (1989). Testing between the TRACE Model and the fuzzy logical model of speech perception. Cognitive Psychology, 21, 398-421.

Massaro, D. W., & Oden, G. C., (1980). Speech Perception: A framework for research and theory. In N. J. Lass (Ed.), Speech and language: Advances in basic research and practice Vol. 3, (pp. 129-165). New York: Academic Press.

McClelland, J. L., & Elman, J. L. (1986). The TRACE model of speech perception. Cognitive Psychology, 18, 1-86.

McQueen, J. M. 1991. The influence of the lexicon on phonetic categorization: Stimulus quality in word-final ambiguity. Journal of Experimental Psychology: Human Perception and Performance, 17, 433-443.

Mertus, J. (1989). Bliss User's Manual. Providence, R. I.: Brown University.

Miceli, G., Caltagirone, C., Gainotti, G., & Payer-Rigo, P. (1978). Discrimination of voice versus place contrasts in aphasia. Brain and Language, 6, 47-51.

Miceli, G., Gainotti, G., Caltagirone, C., & Masullo, C. (1980). Some aspects of phonological impairment in aphasia. Brain and Language, 11, 159-169.

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

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

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

Milberg, W., Blumstein, S., & Dworetzky, B. (1988b). Phonological processing and lexical access in aphasia. Brain and Language, 31, 138-150.

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

Miller, J. L. & Dexter, E. R. (1988). Effects of speaking rate and lexical status on phonetic perception. Journal of Experimental Psychology: Human Perception and Performance, 14, 369-378.

Miller, J. L., Green, K., & Reeves, A. (1986). Speaking rate and segments: A look at the relation between speech perception and speech production for the voicing contrast. Phonetica, 43, 106-115.

Morton, J. (1969). Interaction of information in word recognition. Psychological Review, 76, 165-178.

Morton, J. (1979). Facilitation in word recognition: Experiments causing change in the logogen model. In P. A. Kolers, M. E. Wrolstad, & H. Bouma (Eds.), Processing of visual language. New York: Plenum Press.

Newman, R., Sawusch, J. R., & Luce, P. (1994). The time course of neighborhood and lexical effects in phoneme identification. Poster presented at the 128th meeting of the Acoustical Society of America, Boston, MA, June, 1994.

Newman, R., Sawusch, J. R., & Luce, P. (in press). Lexical neighborhood effects in phonetic processing.

Nooteboom, S. G. (1981). Lexical retrieval from fragments of spoken words: Beginnings vs. endings. Journal of Phonetics, 9, 407-424.

Oldfield, R. C. (1966). Things, words, and the brain. Quarterly Journal of Experimental Psychology, 18, 340-353.

Pickett, J. M. (1980). The sounds of speech communication. Baltimore: University Park Press.

Pitt, M. A. & Samuel, A. G. (1993). An emperical and meta-analytic evaluation of the phoneme identification task. Journal of Experimental Psychology: Human Perception and Performance, 19, 699-725.

Repp, B. H. (1984). The role of release bursts in the perception of [s]-stop clusters. Journal of the Acoustical Society of America, 75, 1219-1230.

Rubenstein, H., Garfield, L., & Millikan, J. A. (1970). Homographic entries in the internal lexicon. Journal of Verbal Learning and Verbal Behaviour, 9, 487-494.

Saffran, E. M., Marin, O. & Yeni-Komshian, G. (1976). An analysis of speech perception and word deafness. Brain and Language, 3, 209-228.

Salasoo, A., & Pisoni, D. B. (1982). Sources of knowledge in spoken word identification. In Research on Speech Perception Progress Report No. 8. Bloomington, IN: Speech Research Laboratory, Indiana University.

Salthouse, T. (1988). Effects of aging on verbal abilities: Examination of the psychometric literature. In Light & Burke (Eds.), Language, memory, and aging. pp. 17-35. Cambridge: Cambridge University Press.

Samuel, A. G. (1981). Phonemic restoration: Insights from a new methodology. Journal of Experimental Psychology: General, 110, 474-494.

Samuel, A. G. (1986). The role of the lexicon in speech perception. In E. C. Schwab & H. C. Nusbaum (Eds.), Pattern recognition by humans and machines: Vol. 1. Speech Perception (pp. 89-111). Orlando, FL: Academic Press Series in Cognition and Perception.

Sawusch, J. R., Newman, R., & Luce, P. (1993). Effects of lexical neighborhood density on phoneme perception. Paper presented at meeting of Psychonomic Society, Washington, D.C., November 1993.

Schwartz, M. F. (1984). What the classical aphasia categories can't do for us, and why. Brain and Language, 21, 3-8.

Stevens, K. N., & Blumstein, S. E. (1978). Invariant cues for place of articulation in stop consonants. Journal of the Acoustical Society of America, 64, 1358-1368.

Stevens, K. N. (1986). Models of phonetic recognition II: A feature-based model of speech recognition. Proceedings of the Montreal Satellite Symposium on Speech Recognition (Twelfth International Congress on Acoustics, McGill University, Montreal, Canada.

Tallal, P., & Newcombe, F. (1978). Impairment of auditory perception and language comprehension in dysphasia. Brain and Language, 6, 13-24.

Tyler, L. (1992). Spoken language comprehension: An experimental approach to disordered and normal processing. Cambridge: MIT Press.

Varney, N. R. (1984). Phonemic imperception in aphasia. Brain and Language, 21, 85-94.

Wang, M. D., & Bilger, R. C. (1973). Consonant confusions in noise: A study of perceptual features. Journal of the Acoustical Society of America, 54, 1248-1266.

Warren, R. M. (1970). Perceptual restoration of missing speech sounds. Science, 167, 392-395.

Wingfield, A., Poon, L., Lombardi, L., & Lowe, D. (1985). Speed of processing in normal aging: Effects of speech rate, linguistic structure, and processing time. Journal of Gerontology, 40, 579-585.

Yeni-Komshian, G. H., & Lafontaine, L. (1983). Discrimination and identification of voicing and place contrasts in aphasic patients. Canadian Journal of Psychology, 37, 107-131.

IMAGE EVALUATION TEST TARGET (QA-3)

150mm

6″

APPLIED IMAGE. Inc
1653 East Main Street
Rochester, NY 14609 USA
Phone: 716/482-0300
Fax: 716/288-5989