1985

Perception of English/Spanish VOT by Monolingual English Speakers: A Dichotic Study

Cynthia Flesher Barrios

PERCEPTION OF ENGLISH/SPANISH VOT

BY MONOLINGUAL ENGLISH SPEAKERS:

A DICHOTIC STUDY

An Abstract of a Thesis

Submitted

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

Cynthia Flesher Barrios

University of Northern Iowa

December 1985

ABSTRACT

Dichotic listening tasks have been used extensively to establish the left cerebral hemisphere as dominant for linguistic processing. Dichotic stress has also been used to investigate lateralization patterns for individuals who speak more than one language and if those patterns differ from those found in monolingual speakers. Most investigations of this nature, with both monolingual and bilingual subjects, have found a right ear advantage (REA) for linguistic processing.

Voice onset time (VOT) is the acoustic parameter primarily responsible for the categorical discrimination of stop consonants in a number of different languages, including English and Spansih. It has been found that the knowledge of more than one language will change the expected categorical boundaries between the stop cognates.

It has also been demonstrated that the reaction time (RT) for right ear responses during a dichotic listening task are consistently faster than RTs associated with left ear responses. These faster RTs have been presented as further evidence for left hemisphere superiority in the processing of both linguistic output and input.

The purpose of the following study was an attempt to utilize dichotic listening techniques and reaction time

measures to obtain more information pertaining to the manner in which linguistic information is perceived and processed. Since mixed language stimuli at the phonological level were employed there was a special interest in determining to what extent language learning history will affect a listener's perceptions at the phonological level under conditions of dichotic stress.

Twenty adults, all right-handed, monolingual speakers, were given a direct recall, one-response dichotic test. The stimuli were composed of paired English and Spanish stop consonant-vowel syllables varied only by the length of the VOT for the initial consonant. Stimuli consisted of cognate pairs with presentations of one syllable in each language. The presentations were also counterbalanced for an equal number of presentations to each ear.

Results indicated that subjects, individually and as a group, demonstrated a no ear advantage (NEA) significantly more often than a right or left ear advantage. This NEA was further confirmed by the fact that subjects identified significantly more English than Spanish syllables independent of the ear of presentation. These results showed that language familiarity, even at the phonological level, served as a more important variable than usual ear dominance patterns in the identification process employed during this dichotic test. The reaction time for right ear responses was not significantly different from the reaction time for left ear responses. Reasons for this lack of difference in reaction times were discussed. Future research uses for this dichotic test, especially with English/Spanish bilinguals, were also discussed.

PERCEPTION OF ENGLISH/SPANISH VOT
BY MONOLINGUAL ENGLISH SPEAKERS:
A DICHOTIC STUDY

A Thesis

Submitted

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

Cynthia Flesher Barrios

University of Northern Iowa

December 1985

This Study by: Cynthia Flesher Barrios

Entitled: PERCEPTION OF ENGLISH/SPANISH VOT

BY MONOLINGUAL ENGLISH SPEAKERS:

A DICHOTIC STUDY

has been approved as meeting the thesis requirement for the Degree of Master of Arts.

Carlin Hageman

11/20/85
Date — Chairman, Thesis Committee

Bruce Plakke

11-20-85
Date — Member, Thesis Committee

Jack Yates

11-20-85
Date — Member, Thesis Committee

John C. Downey

1-30-86
Date — Dean of the Graduate College

ACKNOWLEDGMENTS

I am grateful to Carlin Hageman, Ph.D., my committee chairman, for his knowledge and infinite patience which made this project possible. I would also like to express my thanks to Bruce Plakke, Ph.D., and Jack Yates, Ph.D., my committee members, for their assistance. Last, I would like to express my deepest appreciation to my husband, Frank, for his constant support throughout this endeavor.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

Various researchers have suggested that the left hemisphere of the brain is responsible for the processing of linguistic information for most individuals. For example, Davis (1983) reported that with sodium-amytal injections into the left common or internal carotid artery (Wada test), 90% of right-handers exhibited contralateral, left hemisphere control of language functions, and 10% right hemisphere control. Left-handers showed a more mixed distribution of language function with 48% exhibiting left hemisphere control, 38% right hemisphere control, and 14% bilateral control.

Dichotic listening tasks have also been used to establish left hemisphere dominance for language functions (Berlin & McNeil, 1976; Kimura, 1961). For the majority of monolingual speakers, more verbal auditory stimuli are correctly identified when presented to the right ear than the left, establishing a right ear advantage (REA) for the processing of linguistic stimuli. Kimura postulated that since most of the pathways of the auditory system are crossed, the REA served as additional evidence supporting the left hemisphere as being dominant for speech and language functions.

Springer (1971) developed a method whereby the reaction times (RT) for left ear (LE) and right ear (RE) responses could be separately measured during a dichotic listening task. The author contended that the faster RTs associated with RE responses presented further evidence for left hemisphere superiority in the processing of linguistic information since a nonverbal motor response mode was employed. She also contended that the laterality effects observed during dichotic listening extended not only to the verbal output system, but also to the perceptual system due to the nonverbal response mode which was used.

The study presented in this paper is an attempt to utilize dichotic listening and reaction time to determine the manner in which linguistic information is perceived and processed. Of interest here is the perception of dichotic stimuli composed of mixed language phonological information, the voice onset time (VOT) of stop consonants in Spanish and English. In order to gain additional insight into the manner in which linguistic information is processed, it may prove useful to employ a dichotic presentation task of auditory stimuli varying only in the length of the VOT, and crossing VOT category boundaries of both English and Spanish. Also, the use of mixed language stimuli may produce additional information concerning the role language familiarity plays in phonological perception.

Dichotic studies have been completed with speakers of two or more languages in an attempt to determine if the cerebral organization of language processing was different for bilingual speakers as compared to monolingual speakers. In a review of clinical and experimental studies related to the neuropsychological basis of language processing in bilinguals, Vaid and Genesee (1980) found inconclusive evidence supporting a REA for a second language in bilinguals. The lack of conclusive evidence for a REA for the second language was at least partially due to an inability to accurately compare these bilingual studies. The studies reviewed by Vaid and Genesee were not well matched in terms of either bilingual subject characteristics, or in the stimuli used. Notably, there were differences found between studies in the age at which subjects had learned their second language and their proficiency in second language comprehension and production. Also, in terms of stimuli characteristics, the linguistic characteristics of the different languages were often different enough to make meaningful comparisons impossible, and the linguistic complexity of the verbal stimuli varied from study to study (nonsense syllables, words, or sentences).

In English, the phoneme category of stop or plosive consonants can be categorically differentiated for voicing by the acoustic parameter of VOT. VOT is physically realized by the relative amount of time between the release of the built-up air pressure behind the oral closure and the onset of voicing (Borden & Harris, 1980). This acoustic parameter is used by the listener to perceptually discriminate not only stop consonants from all other English phonemes but also in the discrimination of one stop consonant from the other English stop consonants.

Lisker and Abramson (1964) were able to demonstrate that VOT is also a major means of phonemic discrimination used by the speakers of a number of different languages. They showed that VOT was the major articulatory variable in the discrimination of the three sets of stop cognates in eleven different languages. Also, variability existed across languages as to the location of the categorical boundaries between the voiced/voiceless contrasts along a VOT continuum. VOT manipulation has been one of the techniques employed by researchers to study the nature of phonological acquisition during second language learning, and to differentiate between the perceptual and production skills of bilinguals in their two languages (Albert & Obler, 1978; Caramazza, Yeni-Komshian, & Zurif, 1974; Caramazza, Yeni-Komshian, Zurif, & Carbone, 1973; Williams, 1977, 1979).

The purpose of this study is to determine whether monolingual English speakers will identify only English consonant-vowel (CV) syllables when simultaneously presented with an English CV syllable in one ear and a Spanish syllable in the other. The two syllables will vary only in the length of the VOT for the initial consonant. It is predicted that the listeners will not demonstrate the usual REA for either English or Spanish which is present during most dichotic listening tasks since these subjects will have an established phoneme category for only one of the syllables presented. The physiological make-up of the crossed auditory pathways is such that the contralateral pathways are not only more abundant, but also they transmit stimuli with greater speed and intensity than the ipsilateral pathways (Berlin & McNeil, 1976; Kimura, 1961; McNeil, Pettit, & Olsen, 1981). Based on these physiological considerations, it is predicted that those syllables identified by the right ear will have a shorter reaction time than those identified by the left ear, regardless of the language type of the presented stimuli.

It should be noted that this research project is the first part of a projected larger study. The dichotic task employed in this study will be given at later dates to three additional groups of subjects: Spanish monolinguals, English/Spanish bilinguals, and Spanish/English bilinguals.

Comparison of the data obtained from all four groups will possibly enhance our understanding of linguistic perception at the phonological level. It is also proposed that this dichotic task has the potential for detecting the "dominant," or more readily processed, language in bilingual speakers of English and Spanish.

CHAPTER II

REVIEW OF THE LITERATURE

Dichotic Research

Dichotic Tasks with Monolingual Speakers

Kimura (1961) found that when digits were dichotically presented to patients with unilateral temporal lobectomies, the recognition of digits presented to the ear contralateral to the removal was impaired, but that overall efficiency was markedly worse pre- and postoperatively if the left temporal lobe was dysfunctional. She concluded that the ear contralateral to the dominant hemisphere was more efficient in the recognition of verbal stimuli, and that the dominant hemisphere for the "elaboration of speech sounds" was the left in most individuals, regardless of handedness. This REA for dichotically presented stimuli has been repeated a number of different times (Bartz, Satz, Fennell, & Lally, 1967; Berlin & McNeil, 1976; Broadbent & Gregory, 1964; Bryden, 1963; Studdert-Kennedy & Shankweiler, 1970).

Dichotic Tasks with Bilingual Speakers

A number of studies have employed dichotic listening tasks with bilingual subjects in an attempt to determine if the lateralization of two or more different languages is different than that for individuals knowing only one language. Also, these studies have often examined whether cerebral organization may be different during different stages of learning an additional language, if developmental differences in cerebral organization of two or more languages exist, and if there are differences in cerebral organization dependent on the manner of second language acquisition (formal vs. informal learning).

Galloway and Scarcella (1982) used a dichotic task consisting of English and Spanish words which were presented to adult male Spanish speakers who were informally learning English, and to two control groups, a monolingual English group and a monolingual Spanish group. A significant REA was found for all three groups. The bilingual group had no more difficulty in reporting English words than did the monolingual English or Spanish control groups. These results were interpreted as further support for the claim that the left hemisphere is dominant for language processing in most individuals, and that there is no greater right hemisphere involvement in early, informal second language acquisition.

When a dichotic word test was presented to English-Hebrew adult bilinguals with highly variable language learning histories, a significant REA was found across all subject groups (Gordon, 1980). Gordon concluded that "the cerebral dominance determined in this study was the same for each language, no matter when the second language was learned, how long it had been used, or how well it was known" (p. 265). In another dichotically presented word test where English-Hebrew bilinguals were considered to be a balanced group (subjects had learned both languages before age 12), and were matched with an English dominant group and a Hebrew dominant group, it was found that all demonstrated a REA (Albert & Obler, 1978). The authors determined that the greatest degree of left ear identifications were present when one of the word pairs contained a phoneme found only in Hebrew, though an overall REA was still present. These results were interpreted by the authors to mean that there may be differential dominance patterns for different languages, that these differential patterns will be most apparent when words in two different languages are presented, and that phoneme discrimination in either language is still processed in the left hemisphere.

Research has also been done using bilingual children as subjects. Starck, Genesee, Lambert, and Seitz (cited in Albert & Obler, 1978) compared the cerebral dominance for English in two different age groups of trilingual children who spoke English in the home and were taught in school only in Hebrew and French. They used dichotically presented monosyllabic digits as stimuli. Their results were inconclusive since overall performance increased with age for both groups. The accuracy of the order of recall was better for stimuli presented to the right ear for both age groups.

In another study, Gordon and Zatorre (1981) used pre- or postpubertal Spanish speaking children who were enrolled in bilingual education classes and living in an English speaking environment. These children were asked to identify dichotically presented word pairs in both languages. Results showed that the children demonstrated a "clear and equal" REA for both languages. Neither the fact that the older children scored higher than the younger ones, or that both groups performed better in Spanish seemed to interact with the observed strong REA. This would indicate that the left hemisphere was equally involved in the processing of both languages, at least at the word level, and that this portion of processing was not affected by stage of development or language learning.

In a similar study, Repp (1980) also found a significant REA on two dichotic word tests which were at two different levels of complexity. His subjects were Vietnamese children, ages ranging from 6 to 13, all having lived in the United States for approximately three years at the time of testing. The REA was stronger for English, but significant for both languages. Once again, it was noted that the overall performance in both languages was better for the older children.

Albert and Obler (1978) proposed that there were two different types of bilingual processing. This proposal was based upon an in-depth review of the literature and their own research, including dichotic tasks. These two categories were defined as compound bilingualism (i.e., different neurological storage areas for different languages), and coordinate bilingualism (i.e., same storage area for all languages). Based upon their assumption that there are different levels of neurological processing for different types of linguistic information, they concluded that most bilinguals would make use of both compound and coordinate storage. Further, they predicted that the lower the level of linguistic processing, deep semantic, and phonological perception, the more likely compound storage existed, and the higher the linguistic level, lexical, and syntactic processing, the more probable coordinate storage was present.

A dichotic task which makes use of stimuli from two different languages has the potential for investigating the veracity of Albert and Obler's prediction that phonological processing of different languages takes place in different neurological storage areas. The particular task should be designed to allow for linguistic variation only at the phonological level of processing. Variations of VOT would be good since VOT has been shown to be perceptually specific and distinct for the speakers of different languages (Lisker & Abramson, 1964). Subjects should be asked to recognize and identify only one of two simultaneously presented syllables (a forced choice task), each in a different language. Since only one syllable would be recognized and reported by the subjects, especially if they are monolingual speakers, it would be possible to determine if language familiarity will override the usual ear dominance patterns found during most dichotic tasks.

Heretofore, the dichotic studies reviewed have explored cerebral dominance for language in monolingual and bilingual speakers. The findings, at least from these studies, indicate that the left hemisphere, as shown by a REA during dichotic tasks, is responsible for most linguistic processing, even for bilingual speakers. However, Obler, Zatorre, Galloway, and Vaid (1982) demonstrated that hemispheric specialization for a second language has not always been found in bilingual research. These authors pointed out a number of methodological considerations which must be taken into account when interpreting the results of dichotic studies of bilingualism. These authors make the point that subject homogeneity with bilingual speakers is next to impossible, even within the confines of one study, let alone across studies. Based upon the methodological issues concerning subject selection discussed by these authors, it is necessary to point out that the different genders, ages, levels of second language proficiency, and the manner and age of second language acquisition make it difficult to draw any strong conclusions about ear dominance patterns for bilingual speakers within and across studies.

Also, it must be pointed out that all of the studies reviewed here used stimuli at the word level rather than at the lower phonological level. Thus, it is possible to conclude only that left hemispheric control is present for most bilinguals at the word level of linguistic processing. This would be in accord with Albert and Obler's (1978) contention that coordinate storage exists for lexical processing, but it tells us nothing about the possibility of compound storage for phonological information.

In a dichotic listening task, the linguistic characteristics of the two compared languages may also be a factor in the interpretation of the results. The closeness or distance of the linguistic characteristics of the two compared languages may influence how they are processed. Spanish and English, which were compared by Galloway and Scarcella (1982), and Gordon and Zatorre (1981), are more genetically related, therefore contain more comparable stimuli, than the Hebrew and English combination employed by Gordon (1980), and Albert and Obler (1978), or the Vietnamese and English combination used by Repp (1980).

Also, as pointed out by Obler et al. (1982), the temporal alignment of stimuli is crucial for any meaningful interpretation of dichotic results. If one of the dichotic pairs "precedes another by as short as 20 msec, an accuracy advantage accrues to the delayed stimuli" (p. 46). In the studies reviewed here, the words used as stimuli pairs were not well defined in terms of temporal alignment differences. Therefore, it is not possible to determine how precisely onset and offset alignments were controlled for.

Studies of Voice Onset Time

Cross-Language Variability in VOT

Lisker and Abramson (1964) demonstrated that VOT was the articulatory characteristic which was responsible for the perceptual separation of stop cognates in eleven different languages. The stop categories had well defined ranges along the VOT continuum which were distinct for each language. Lisker and Abramson (1970) showed that English VOT values for all three places of articulation were longer than those in Spanish. In English, /b, d, g/ were produced with zero VOT or a small voicing lag, while /p, t, k/ all showed a voicing lag of between 58 to 80 msec. For Spanish, /b, d, g/ were all produced with a voicing lead of between 138 to 108 msec, with /p, t, k/ at zero VOT or a short voicing lag. There is an overlap of VOT values for the voiced English and the voiceless Spanish cognates. In terms of discrimination, it was found that there was a "sharpening of discrimination at the phoneme boundaries" (p. 570) and that this discrimination was determined by an individual's specific language experiences (Abramson & Lisker, 1970).

Bilingual Perception of VOT

Based upon cross-language studies of VOT, research has been conducted using the phonological feature of VOT as a variable to determine how bilinguals identify their two languages at the phonological level, and to determine if their perceptions are the same as monolingual speakers.

Caramazza, Yeni-Komshian, Zurif, and Carbone (1973) tested the perception and production of stop consonants in French-Canadian bilinguals. Among their findings, the perceptual results are of particular interest here. The subjects, all of whom had acquired English before age 7, were asked to identify whether they had heard the voiced or voiceless form of the three stop cognates. The stimuli were composed of randomly presented synthesized stops which ranged from negative to positive VOT values. When compared to monolingual English and French speakers, the bilinguals showed a categorical boundary which was intermediate between either of the two monolingual groups. In a later study, Caramazza, Yeni-Komshian, and Zurif (1974) found that even when French-Canadian bilinguals were placed in a situation which would create a "psychological set" for either English or French (i.e., all instructions to or conversation with the subjects were only in English or French), the subjects were able to perceive and categorize syllables in both languages when the initial consonant was varied along the VOT continuum. Since the authors had suggested in the earlier study that VOT was a less important distinctive feature in French than English, they concluded that "preattentive mechanisms," employed by bilinguals to categorize what language they were hearing, need not be at the semantic level but extended down to the phonological level. In other words, the bilingual can identify the language being heard very early in the processing sequence. Albert and Obler (1978) found similar performance in Hebrew and English speaking listeners. They reported that Hebrew and English bilinguals categorically perceived the voiced-voiceless boundaries of the stop cognates somewhere between the points where monolingual Hebrew and English speakers perceived them. Also, they determined that VOT was a less important phonemic marker in Hebrew than English since the Hebrew identifications showed a wider range of variation implying less significance for the VOT cue. Once again though, differential language perceptions were apparent at the phonological level.

Williams (1977) conducted a study in which Spanish and English bilinguals were asked to identify synthesized CV syllables in which the VOT for stops was systematically varied. Three of the subjects had first learned English, and five had first learned Spanish, but all used both languages in their daily lives. Williams suggested that bilinguals cannot perceptually separate both the Spanish and English voicing contrasts since the subjects showed a predisposition to identify either closer to the monolingual Spanish or monolingual English voiced-voiceless boundaries. A possible alternative explanation is that the subjects were identifying voicing contrasts closer to the more readily processed, or "dominant," language.

In summary, VOT is variable and distinctly different between languages. Apparently, a listener perceives and categorizes it according to their past language experiences. The research reviewed here indicates that the knowledge of more than one language will cause a change in the expected categorical boundaries between the cognates. The categorical boundaries for bilingual speakers have been found to be at an intermediate point between either of the two languages spoken. Further, the stimuli in all of these studies were composed of CV syllables varied along the VOT continuum. Researchers investigated how the bilingual speakers' language learning history affected their categorical perceptions of VOT values, not whether they could more readily identify the VOT values of one language in comparison to another. None of these studies have attempted to test the perception of VOT within the context of a dichotic listening task.

Stop Consonant Perception During Dichotic Presentation

A few studies have explored monolingual speakers' perception of voiced-voiceless stop consonants using dichotically presented syllables. Berlin and McNeil (1976) used CV syllables comprising the six English stop consonants all followed by the neutral vowel /ɑ/ as stimuli. For some presentations they used synthesized speech while in others they employed naturally spoken syllables. They were able to consistently obtain a strong REA, regardless of the type of stimuli used. They also reported certain phonetic contexts which affected the accuracy of identification, and the strength, of the REA. These authors found that voiceless stop consonants were more readily identified than voiced, and that "the velar syllables were reported correctly more often than were the alveolar syllables, and the latter, in turn, were reported more accurately than the labial syllables" (p. 339). Berlin and McNeil also concluded that acoustic and phonetic competition in dichotic tasks increased the likelihood of observing the right ear advantage as compared to when higher levels of linguistic competition were used. Thus, they questioned whether dichotic stimuli which were varied only by phonological or acoustic parameters were tapping the subject's language processing system or processes used in speech perception only. However, if English monolingual listeners base their identifications of Spanish/English CV syllables upon their familiarity with the stimuli rather than usual ear dominance patterns, it would then seem that dichotically presented, phonologically varied stimuli would be tapping the subject's language processing system.

In an earlier study, Studdert-Kennedy and Shankweiler (1970) employed naturally spoken consonant-vowel-consonant (CVC) syllables which were composed of varying pairs of the stop consonants and the six pure vowels of English. These syllables were randomly paired and presented to subjects simultaneously. Like Berlin and McNeil (1976), they found that the voiceless stops were more easily recognized than were the voiced, but in terms of place of articulation, the alveolars were least affected by dichotic stress, followed by the velars and the labials. They concluded:

> (1) a significant right-ear advantage for initial stop consonants; (2) a significant, though reduced, right-ear advantage for final stop consonants; (3) a nonsignificant right-ear advantage for six medial vowels; and (4) significant and independent right-ear advantages for the articulatory features of voicing and place in initial stop consonants. (p. 592)

They also stated that the consistent REA observed in the perception of stop consonants is due to the dominant hemisphere's specialization for the "extraction of linguistic features" from the many parameters which make up the speech signal.

In summary, monolingual speakers have demonstrated a consistent REA when asked to correctly identify voiced-voiceless stops in CV and CVC pairs during dichotic presentations. It was found that the voiceless stops were the least affected by dichotic stress. Only English stop consonants were used for the stimulus presentations in either of these studies.

Auditory Processing During Dichotic Listening

Reaction Times During Dichotic Presentations

Springer (1971) dichotically presented CV syllables, patterned after those employed by Studdert-Kennedy and Shankweiler (1970), to twelve right-handed college students. Subjects were instructed to depress a hand-held response button as quickly as possible for each occurrence of the syllable /dɑ/. Subjects were able to detect the target syllable when presented to the RE with 97.6% accuracy, while the LE responses were accurate 91.4% of the time. A mean of the medians of the RTs for all subjects showed an overall RT of 579 msec for LE targets and 529 msec for RE targets. In other words, these subjects were able, on the average, to detect a target syllable in the RE 50 msec more quickly than in the LE.

The author interpreted these results as showing that the laterality effects seen during dichotic tasks apply not only to the verbal output system, but also to the verbal perceptual system. This interpretation was based on the fact that responses were not made verbally but through a nonverbal motor mode. The author offered two possible interpretations for the RT differences found. The first was that the longer RTs observed in LE responses were due to the extra time needed for the transfer of right hemisphere information to the left for processing. This interpretation assumes that all verbal information is processed in the left hemisphere. The alternative view states that the longer RT for LE responses is due to the additional time needed by the less efficient right hemisphere to process verbal information.

In a later study, Springer (1973) asked 20 right-handed college students to move a lever in one direction if they heard the target syllable /bɑ/ or in the opposite direction if they heard any of the other five English stop consonant CV syllables. Each dichotic presentation consisted of one of the six possible CV syllables to one ear and white noise to the other. Results were as follows: subjects were able to perform this task practically without error; they were able to detect the presence of the target syllable significantly more quickly than its absence; and they were able to respond to RE presentations of syllables significantly more quickly (an average of 14 msec) than those to the LE. Springer interpreted these results as additional evidence that the perceptual class of dichotic stimuli does not need to be the same (i.e., white noise and syllables) for ear asymmetry to exist, and that the 14 msec latency between LE and RE responses reflects the callosal transmission time needed for the transfer of LE information to the left hemisphere for speech processing.

Ipsilateral and Contralateral Pathways in Dichotic Listening

A few dichotic studies have been done with patients who have had partial or complete sectioning of the corpus callosum to control epileptic seizures. It has been suggested that these patients are the best subjects to study the role of contralateral and ipsilateral auditory pathways during auditory perception. McNeil, Pettit, and Olsen (1981) concluded, based upon the results of dichotic listening tasks, that the "ipsilateral auditory pathways' (IAP) role is secondary to the contralateral in transmitting information to the cortex" (p. 78), and the IAPs are actually suppressed during dichotic listening.

Springer and Gazzaniga (1975) tested four patients with differing amounts of the corpus callosum sectioned. Each subject was tested under three different conditions:

standard dichotic presentation, dichotic presentation with instructions to attend to the nondominant ear, and monotonic presentation (stimuli presented to one ear only) of single syllables. The stimuli was composed of the six stop consonants paired with the vowel /ɑ/. Performance among subjects varied according to which portion of the cerebral commissural fibers had been sectioned. In general, the data indicate that with the appropriate portion of the corpus callosum sectioned (sections anterior to the splenium and posterior to the first one-third of the corpus callosum), "right-handed subjects were unable to report any of the CV syllables presented to the LE even under condition two which was designed to optimize processing and output opportunities in favor of that ear" (Springer & Gazzaniga, 1975, p. 344). Monotonic presentation to the LE, though, resulted in good CV identifications. These results support the notion that the IAPs are suppressed during dichotic presentations. However, Springer and Gazzaniga did not believe that their data could explain whether the lack of LE identification during dichotic presentation was due to the inability of the right hemisphere to process verbal inputs, or due to a unilateral neglect of the LE. They went on to suggest that more attention must be given to the nature of the phonetic and semantic content of the dichotic stimuli before this issue could be resolved.

McNeil, Pettit, and Olsen (1981) presented stop consonant CV syllables to two patients with complete hemispherectomies. In one condition, the two syllables were presented simultaneously, and in the other, they were presented with a 90 msec lag between the two syllables. The subjects were asked to mark which two syllables were heard from six possible choices. From these responses, two types of errors, blend and non-blend errors, could result. Blend errors occurred when the distinctive feature of place from one ear was combined with the distinctive feature voice from the other. Non-blend errors occurred when only one of the features was preserved. For both conditions, subjects were able to identify syllables presented to the RE with 77 to 100% accuracy, but only from 22 to 30% accuracy for the LE. There was no significant difference between the occurrence of blend errors and non-blend errors across conditions. The lack of distinctive feature confusion noted in the error analysis was considered to be evidence that the IAPs were suppressed during the dichotic task and was believed to be evidence that information was being received from only one source, the contralateral pathway.

In summary, the shorter RTs observed in the processing of verbal information by the dominant ear serve as further evidence that the left hemisphere is primarily responsible for not only verbal output, but also verbal perceptual processing. Also, the inability of patients with differing degrees of midline hemsipheric sectioning to identify dichotically presented nonsense syllables to the nondominant ear and their lack of distinctive feature confusion in their error types indicates that the IAPs are indeed suppressed during dichotic listening. Based upon these assumptions concerning the nature and role of the auditory pathways during dichotic listening, it is predicted that monolingual English speakers will continue to demonstrate shorter RTs for RE identifications, even when mixed language stimuli are employed.

Purpose

The purpose of this study is to determine to what extent language learning history will affect the listener's perceptions at the phonological level. Previous dichotic studies which have used mixed language stimuli have only employed test items at the word level. Studies which have been concerned with mixed language perception at the phonological level have not tested the subjects' categorical perceptions along the voicing continuum under conditions of dichotic stress, or with the control of specific onset and offset alignments for the VOT values. The present study attempts to combine these two approaches by asking subjects to identify which mixed language stimuli they recognize when it is varied at the phonological level and presented dichotically. Specifically, is linguistic familiarity with the VOT values of the initial consonant a more important variable in the recognition and recall of CV syllables than whether the stimuli are presented to the dominant or nondominant ear? Also, the measure of RTs for RE and LE responses may also further define the exact nature and role of the ipsilateral and contralateral auditory pathways during phonological perception. If the RE responses continue to occur more rapidly, even when the REA is no longer demonstrated due to a lack of subject familiarity with the stimuli, it will serve as one more piece of evidence for the superiority of the left hemisphere in the processing of verbal information.

Specifically, the following questions will be asked:

1. Will monolingual English speakers demonstrate an ear advantage during a dichotic listening task when the stimuli are composed of one English and one Spanish CV syllable, varied only by the length of the VOT for the initial consonant?

2. Will monolingual English speakers identify more English CV syllables than Spanish CV syllables during a dichotic listening task when the syllables are varied only by the length of the VOT for the initial consonant?

3. Will monolingual English speakers demonstrate a shorter reaction time for all syllables identified in the RE independent of the language of the CV syllables?

CHAPTER III

METHODS

Subjects

Twenty adults, ten male and ten female, comprised the sample population. All subjects were determined to be right-handed using a handedness questionnaire (Bryden, 1977; Oldfield, 1971). Nineteen subjects were native English speakers without previous formal or informal exposure to Spanish. One subject's first language was French but he had used English as his primary language since age 6. Each subject's hearing was determined to be better than 25 dB HTL bilaterally (American National Standards Institute, 1972) for the frequencies of 0.5, 1, and 2 kHz, with an average between-ear-difference of no more than 10 dB.

Stimulus Materials

The CV pairs used in the dichotic test were produced by a monolingual English speaker with extensive knowledge of VOT variations across languages. Five samples of each CV pair, in each language, were recorded on a TEAC A-3300SX tape recorder. These samples were analyzed spectrographically on a Kay Electric 7800 digital sono-graph to select the samples containing the target VOT values to be used in the preparation of the dichotic test tape. (See Table 1 for the VOT values used on the dichotic test tape.)

Table 1

VOT Values of the Dichotic Stimuli

	Syllables					
Language	pa	ba	ta	da	ka	ga
English	39	8	74	8	73	18
Spanish	8	-143	8	-101	18	-78

Note. All values in milliseconds.

Onset and offset alignments of the VOT for the consonants were prepared using the Vocal Program at the Waisman Center, University of Wisconsin, Madison, and were accurate to within 2 msec. Under computer control the stimuli were recorded onto a two-channel tape with each CV pair recorded twice in random order. Due to mechanical failure during this recording process, it was necessary to re-record all stimulus items. Response choices were printed on 5" x 7" cards, counterbalanced for right and left placement on the cards. Each card presented a cognate pair.

The dichotic test consisted of the stop consonants /p, b, t, d, k, g/, all paired with the vowel /ɑ/. Each stimulus presentation was made up of cognate pairs representing all possible combinations of VOT values for each place of articulation. There was a 15-second interval between each stimulus presentation and a total of 72 dichotic presentations.

Procedures

Subjects were given the following instructions: "You will be hearing a syllable in each ear. They will begin with the following sounds: p, b, t, d, k, or g. Choose the syllable you hear most clearly. Guess, even when you are not sure which sound you heard."

The subjects were then instructed to place the palm of their right hand on a hand rest and point to their response with their index finger. The 5" x 7" card described previously was placed directly in front of the hand rest and upon an apparatus for switching off a timer. After indicating their response, the subjects changed the response card with their left hand and waited for the next stimulus item. Five practice trials were administered before the dichotic test to make sure the subjects had understood all instructions.

Apparatus

The dichotic stimuli were presented via a GS-1704 audiometer. Each stimulus was presented at 65 dB HTL through TDH 39 earphones.

The reaction time data were collected using a device designed and constructed by B. Plakke, Ph.D., University of Northern Iowa. It consisted of a wooden frame (approximately 17.5" x 7.25") with a plywood bottom. A plastic piece (approximately 10.5" x 7.25"), mounted on a pivot at midline, was attached to the plywood. Two microswitches that regulated timer offset were positioned under the plastic piece.

During the dichotic test procedures, the headphone output of a two-channel tape, one half-track stereo tape recorder was routed to the start switch of a Hunter voice-activated relay (model 3205) which switched on a timing instrument (Lafayette clock/counter, model 54035) at the start of each command. The timer continued until the subjects made their response choice by touching the response card. Since the response card was lying on the plastic piece of the wooden box, touching the response card depressed one of the microswitches, which in turn shut off the timer.

Statistical Analysis

The phi correlation coefficient, as described by Kuhn (1974), was used to determine the magnitude and direction of ear advantage for each subject. The formula,

$$\text{phi} = \frac{R - L}{\sqrt{(R + L)[2T - (R + L)]}}$$

where R is the total number of RE responses, L is the total number of LE responses, and T represents the total number of response trials, was used. This index yields a positive score, REA, negative score, LEA, or no significant ear advantage (NEA). The significant, or "critical," values of this index were found by:

$$\text{phi} = \sqrt{\frac{\text{chi}^2}{N}}$$

where chi^2 is the value of $\text{chi}^2{}_{1df}$ with the desired significance level, and N is the total number of responses (Kuhn, 1974). A comparison of the ear advantage results was made by using a complex chi-squared to determine if there was a significant ear advantage type (REA, LEA, or NEA) for the group.

Two *t*-tests for related measures were computed. First, the *t*-test for related measures was employed to determine if significantly more English responses were made in comparison to Spanish responses for the entire dichotic test. Second, a *t*-test for related measures was also used to determine if the RT of RE responses for the group were significantly shorter than LE responses. A one-way analysis of variance for repeated measures was employed to determine if significant differences between language responses existed for each half of the dichotic test (Steinmetz, Romano, & Patterson, 1981). The Tukey Method of Multiple Comparisons was used to test for specific mean differences (Hopkins & Glass, 1978).

Reliability

All syllable pairs were randomly presented twice. The Pearson Product-Moment Correlation (Steinmetz et al., 1981) and the Sign Test (Shearer, 1982) were used to determine the consistency and direction of change between the first and second presentations of each item of the test.

CHAPTER IV

RESULTS

Analysis of Ear Preference

As noted previously, the 20 subjects who participated in this study were right-handed monolingual English speakers. The stimuli pairs comprising the test items were composed of one English and one Spanish CV syllable, varied only by the length of the VOT for the initial consonant. The total number of RE and LE responses for each subject were tallied for the two repeated trials separately (36 responses each trial), and then, for the entire dichotic test (72 responses total).

The phi coefficient (Kuhn, 1974) was employed to determine the ear preference score (EPS) for each subject. This coefficient indicated both the magnitude and direction of the ear advantage for each subject. The positive values derived from this coefficient indicated a REA and negative values, a LEA. By solving the equation proposed by Kuhn (1974), and described in Chapter III, the smallest or "critical" value of the EPS for a 72 response task was determined to be .163 ($p < .05$). Any EPS less than this value indicated that the magnitude of the response was so small as to indicate a NEA. As illustrated in Table 2, three of the subjects demonstrated a significant REA, five

Table 2

Number of Right Ear (RE) and Left Ear (LE) Responses by Subject, and the Ear Preference Scores (EPS) and Significant Ear Advantages (SEA) Derived From Those Scores

	Responses			
Subjects	RE	LE	EPS	SEA
1	36	36	.000	NEA[a]
2	45	27	.25	REA[b]
3	35	37	-.028	NEA
4	30	42	-.167	LEA[c]
5	22	50	-.389	LEA
6	44	28	.222	REA
7	33	39	-.083	NEA
8	35	37	-.028	NEA
9	32	40	-.111	NEA
10	30	42	-.167	LEA
11	33	39	-.083	NEA
12	35	37	-.028	NEA
13	35	37	-.028	NEA
14	36	36	.000	NEA
15	40	32	.111	NEA

Table 2 (continued)

	Responses			
Subjects	RE	LE	EPS	SEA
16	33	39	-.083	NEA
17	29	43	-.194	LEA
18	26	46	-.278	LEA
19	55	17	.528	REA
20	36	36	.000	NEA

[a]No Ear Advantage. [b]Right Ear Advantage. [c]Left Ear Advantage.

a significant LEA, and 12 a nonsignificant ear advantage, or NEA.

A complex chi-squared (2 x 3) was computed to determine if one of the three possible ear advantage types occurred significantly more frequently than the other two types. The results, $\chi^2(2, N = 20) = 10.00$, indicated that the NEA occurred significantly more frequently than either the REA or the LEA ($p < .05$), and the REA and LEA were not significantly different from each other.

Analysis of Language Responses

A *t*-test for related measures was employed to determine if significantly more English responses were made in comparison to Spanish responses by the group for the entire dichotic test. As predicted, significantly more English responses were made (M = 62.4) than Spanish responses (M = 10.1), $t(20) = 17.75$, $p < .05$.

A one-way analysis of variance for repeated measures was completed on the different language responses for each of the repeated halves of the dichotic test. Results, $F(3, 72) = 474.87$, $p < .05$, indicated that type of language response varied significantly. (See Table 3 for a summary of this information.) Since the ANOVA was significant, a Tukey Test for Multiple Comparisons was conducted which showed that the number of English and Spanish responses varied significantly from each other on both halves of the test. Further comparisons also indicated that the number of English responses were significantly different from the first and second halves of this dichotic test. Similar results were found when mean number of Spanish responses for each half of the test were compared.

Analysis of Reaction Time Data

A *t*-test for related measures was computed to determine if the RT for the RE responses was significantly shorter than for the LE. The results indicated that the RT for RE

Table 3

One-Way Analysis of Variance for Related Measures: Comparison of English and Spanish Responses From Each of the Repeated Halves of the Dichotic Task

Source	Sum of squares	Degrees of freedom	Mean squares	*F*-ratio
Between	14107.4	3	4702.467	474.87*
Within	752.6	76	9.903	

*Significant $p < .05$.

responses ($M = 1.22$) was not significantly different from the RT for LE responses ($M = 1.17$), $t(20) = .84$, $p > .05$.

Reliability

A Pearson product-moment correlation coefficient was computed to determine the degree of subjects' response consistency between the first and second halves of the dichotic test. The value ($r(20) = .84$) was significant ($p < .05$), indicating that each subject's responses from the first to the second repeated halves of the test were reliable. The Sign Test (Shearer, 1982) results, $z = 3.89$, $p < .05$, indicated that significantly more subjects made a greater number of RE responses on the second half of the test than the first. These two calculations taken together show that even though subject rank order remained consistent from the first and second halves of the test, the changes that did occur were usually to a greater number of RE responses on the second half and these shifts apparently occurred to the same extent for each listener.

Summary

1. The subjects demonstrated a no ear advantage significantly more often than either a right or left ear advantage, which were not significantly different from each other.

2. The subjects identified significantly more English syllables than Spanish syllables.

3. The reaction time for right ear responses was not significantly different from the reaction time for left ear responses.

4. Split-half reliability ($\underline{r}$ = .84) was judged to be adequate for this investigation. However, a systematic shift toward more right ear responses on the second half occurred, but it occurred equally across subjects so that rank order was maintained.

CHAPTER V

DISCUSSION

Demonstrated Ear Preference

That a right ear advantage (REA) is present during dichotic listening tasks has been well documented in the literature. This effect has been consistent and strong with right-handed subjects when the paired stimuli have both been in the same language (Berlin & McNeil, 1976; Kimura, 1961; McNeil, Pettit, & Olsen, 1981; Springer, 1971; Studdert-Kennedy & Shankweiler, 1970). A REA, though less consistent and strong, has also been demonstrated with bilingual subjects when mixed language stimuli have been employed (Albert & Obler, 1978; Galloway & Scarcella, 1982; Gordon, 1980; Gordon & Zattore, 1981; Repp, 1980; Starck, Genesee, Lambert, & Seitz, 1978).

In this study, monolingual English speakers were dichotically presented with mixed language stimuli, varied at the phonological level. The stimuli were counterbalanced for language type so that an equal number of English and Spanish stimuli were heard in each ear. Since the subjects were only familiar with English, and the different stimuli types were counterbalanced for ear of presentation, it was predicted that language familiarity would overcome the usually demonstrated REA. This prediction has been verified by the fact that a significant number of subjects, individually and as a group, demonstrated a no ear advantage (NEA) during this particular dichotic listening task.

It is of interest to note that 13 of the 20 subjects did obtain negative ear preference scores (EPS), which does indicate at least a slight LE bias (see Table 2). However, only five of the negative EPSs were significant, indicating a LEA. But it would have seemed reasonable in the light of previous research that a greater number of the EPSs would have been positive, indicating a RE bias. Due to some problems encountered during the recording of the dichotic test tape, the left channel of the tape was somewhat clearer than the right channel. This slight difference between the two channels may have accounted for this unexpected small bias for the LE.

It is difficult to directly compare this study to previous dichotic studies which have obtained significant REA results. In studies which have used paired stimuli where all items have been in the same language, and presented to monolingual speakers of that language, the subjects were familiar with both items in the paired stimuli. In those cases, item identification probably was based on usual ear dominance patterns rather than stimulus familiarity. In studies where bilingual subjects were presented with mixed language stimuli, the subjects, to a greater or lesser degree, were once again familiar with both stimulus items. The results from these later studies have shown less consistent ear dominance patterns. Based on the results of this study, it may be that at least some of the variability of results from these bilingual dichotic studies may be due to the variability of individual subject's familiarity with one of the two presented languages.

Language Responses

The monolingual subjects in this study identified significantly more syllables with English VOT values for the consonant than those with Spanish VOT values. (See Table 4 for mean number of language responses.) These results serve to confirm and explain the significant NEA previously discussed. The subjects consistently identified the syllable containing the familiar VOT value. It was also found that there were significant differences between the number of English responses for each half of the test, and for the Spanish responses, also. However, the statistical power for finding those differences was large because of the large number of responses and the small degree of variability. Even though the differences were statistically significant, they may not be meaningful differences. One should note that the differences between Spanish and English responses were much larger than the same language type differences.

Table 4

Mean Number of English and Spanish Responses for the Two Halves of the Dichotic Test (Trial 1, Trial 2)

Trial 1 (n = 36)		Trial 2 (n = 36)	
English	Spanish	English	Spanish
29.75	6.25	32.65	3.35

The stimuli used in this study were not at a semantically meaningful linguistic level. They were nonsense syllables varied at the phonological level, specifically, the length of the VOT for the CV syllables. The results of this study would seem to indicate that language recognition does take place at the phonological level. These findings support the earlier ones of Abramson and Lisker (1970) that phoneme discrimination is determined by a listener's specific language experiences.

Previous studies (Albert & Obler, 1978; Caramazza, Yeni-Komshian, Zurif, & Carbone, 1973; Williams, 1977) have shown that bilingual speakers demonstrated categorical perceptual cross-over points on the voicing continuum which were intermediate to those of monolingual speakers. It would be of interest to see how English/Spanish bilinguals would respond if given the dichotic task employed in this study. There were three different pairs of stimuli used in this task which could be considered as ambiguous for an English/Spanish bilingual. The VOT values for the pairs, Spanish /pɑ/-English /bɑ/, Spanish /tɑ/-English /dɑ/, Spanish /kɑ/-English /gɑ/, were the same (see Table 1). It may be that consistent language responses on these particular items by an English/Spanish bilingual might be considered as an indication that the language of response is the more readily processed, or the "dominant" language for that individual. It might also be that overall response patterns on all of the stimulus items used in this test could be interpreted as an indication of language accessibility, especially in cases where responses on the ambiguous items were less consistent.

Reaction Time

Springer (1971, 1973) found that during dichotic listening, the reaction time (RT) for RE responses was less than that for LE responses. Reaction times were measured in this study and no significant differences were found between the ear of response.

There are several variables which may account for this lack of difference. First, the level of difficulty in this dichotic study was considerably greater than that in either of Springer's studies. In the two studies cited above, subjects were required to identify English CV syllables only, and in the later study, the syllables were opposed in the opposite ear only by white noise. Also, Springer (1971) instructed her subjects to respond as quickly as possible, which was not done in this study.

In this study, also, the manner in which reaction time was measured may not have been sensitive enough to measure small, but significant, differences in RT. Springer (1973) had her subjects hold a lever throughout the test and push it when making a response. In this study, a pointing response was required. Even though a hand rest was provided to control for hand position, there was variability between subjects in the manner in which they held the index finger while waiting for stimulus presentations. In some cases, subjects held the index finger ready to respond throughout the test, while others rested it on the hand rest while waiting for the next stimulus presentation. The accuracy of RT measures taken with this dichotic task would be improved if stimulus presentations could be made on a computer, and responses and RTs measured via the use of a joystick.

Patterns of Auditory Processing

Because no differences were found in the RTs, it is not possible to make any inferences concerning the patterns of auditory processing used during this task. Based on the results of this study, it is not possible to determine if the NEA demonstrated by most subjects indicated equal processing in both hemispheres, or if a continuation of usual patterns of left hemispheric processing existed. It is also not possible to make any statements concerning the proposal made by McNeil, Pettit, and Olsen (1981) that the ipsilateral pathways were suppressed, or weakened, during this dichotic task.

Future Research Considerations

As stated earlier in this paper, this study is only the first part of a proposed larger study. One area of interest within the context of this larger study will be to see if monolingual Spanish speakers will demonstrate a NEA like the monolingual English speakers in this study, but with a Spanish language bias.

Of greater interest and complexibity will be to see if any type of consistent response patterns can be found with English/Spanish and Spanish/English bilinguals. As stated earlier, the ambiguous stimulus items may in themselves be enough to determine a possible language accessibility bias, or possibly overall response patterns to all stimulus items may be more discriminating in detecting a bias. It is also possible that a few bilinguals may be so balanced in the processing of their two languages that usual ear dominance patterns could be demonstrated.

It would also be of interest to determine if bilingual response patterns with this dichotic task would correlate in some manner with individual language learning variables. Some of the variables which could be considered are language first learned, the language spoken more at the time of testing, the age and manner in which the second language was acquired, or other sociolinguistic variables such as linguistic milieu (i.e., where and when each language is spoken as well as attitudes toward each language).

The results of this study are promising for the future use of this particular dichotic task. Finer measurements of RT may lead to further knowledge concerning the nature of auditory processing of linguistic input. Also, it would seem that the design of this dichotic task has the potential for resolving a number of issues concerning both monolingual and bilingual phonological perceptual processes.

REFERENCES

Abramson, A. S., & Lisker, L. (1970). Discriminability along the voicing continuum: Cross language tests. In B. Hala, M. Romport, & P. Janota (Eds.), Proceedings of the Sixth International Congress of Phonetic Sciences (pp. 569-573). Prague: Academia.

Albert, M. L., & Obler, L. K. (1978). The bilingual brain. New York: Academic Press.

American National Standards Institute (1972). Specifications for audiometers (ANSI 53.6-1969). New York: American National Standards Institute, Inc.

Bartz, W. H., Satz, P., Fennell, E., & Lally, J. R. (1967). Meaningfulness and laterality in dichotic listening. Journal of Experimental Psychology, 73, 204-210.

Berlin, C. I., & McNeil, M. R. (1976). Dichotic listening. In N. J. Lass (Ed.), Contemporary issues in experimental phonetics (pp. 327-387). New York: Academic Press.

Borden, G. J., & Harris, K. S. (1980). Speech science primer. Baltimore, MD: Williams & Wilkins.

Broadbent, D. E., & Gregory, M. (1964). Accuracy of recognition for speech presented to the right and left ears. Quarterly Journal of Experimental Psychology, 16, 359-360.

Bryden, M. P. (1963). Ear preference in auditory perception. Journal of Experimental Psychology, 65, 103-105.

Bryden, M. P. (1977). Measuring handedness with questionnaires. Neuropsychologia, 15, 617-624.

Caramazza, A., Yeni-Komshian, G. H., & Zurif, E. B. (1974). Bilingual switching: The phonological level. Canadian Journal of Psychology, 28, 310-318.

Caramazza, A., Yeni-Komshian, G. H., Zurif, E. B., & Carbone, E. (1973). The acquisition of a new phonological contrast: The case of stop consonants in French-English bilinguals. The Journal of the Acoustical Society of America, 54, 421-428.

Davis, G. A. (1983). A survey of adult aphasia. Englewood Cliffs, NJ: Prentice-Hall.

Galloway, L. M., & Scarcella, R. (1982). Cerebral organization in adult second language acquisition: Is the right hemisphere more involved? Brain and Language, 16, 56-60.

Gordon, D. P., & Zatorre, R. J. (1981). A right-ear advantage for dichotic listening in bilingual children. Brain and Language, 13, 389-396.

Gordon, H. W. (1980). Cerebral organization in bilinguals: Lateralization. Brain and Language, 9, 255-268.

Hopkins, K. D., & Glass, G. V. (1978). Basic statistics for the behavioral sciences. Englewood Cliffs, NJ: Prentice-Hall.

Kimura, D. (1961). Cerebral dominance and the perception of verbal stimuli. Canadian Journal of Psychology, 15, 166-171.

Kuhn, G. M. (1974). The phi coefficient as an index of ear differences in dichotic listening. Cortex, 9, 450-457.

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

Lisker, L., & Abramson, A. S. (1970). The voicing dimension: Some experiments in comparative phonetics. In B. Hala, M. Romport, & P. Janota (Eds.), Proceedings of the Sixth International Congress of Phonetic Sciences (pp. 563-567). Prague: Academia.

McNeil, M. R., Pettit, J. M., & Olsen, W. O. (1981). Ipsilateral auditory pathway suppression in dichotic CV speech perception: Evidence from error analysis. Journal of Speech and Hearing Disorders, 46, 87-90.

Obler, L. K., Zatorre, R. J., Galloway, L., & Vaid, J. (1982). Cerebral lateralization in bilinguals: Methodological issues. Brain and Language, 15, 40-54.

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh Inventory. Neuropsychologia, 9, 97-113.

Repp, J. H. (1980). Cerebral language dominance in Vietnamese-English bilingual children (Doctoral dissertation, University of New Mexico, 1980). Dissertation Abstracts International, 41, 2090A.

Shearer, W. M. (1982). Research procedures in speech, language, and hearing. Baltimore, MD: Williams & Wilkins.

Springer, S. P. (1971). Ear asymmetry in a dichotic detection task. Perception & Psychophysics, 10, 239-241.

Springer, S. P. (1973). Hemispheric specialization for speech opposed by contralateral noise. Perception & Psychophysics, 13, 391-393.

Springer, S. P., & Gazzaniga, M. S. (1975). Dichotic testing of partial and complete split brain subjects. Neuropsychologia, 13, 341-346.

Starck, R., Genesee, F., Lambert, W., & Seitz, M. (1978). Multiple language experience and cerebral dominance. In M. L. Albert & L. K. Obler (Eds.), The bilingual brain (pp. 193-194). New York: Academic Press.

Steinmetz, J. E., Romano, A. G., & Patterson, M. M. (1981). Statistical programs for the Apple II microcomputer. Behavior Research Methods and Instrumentation, 13(5), 702.

Studdert-Kennedy, M., & Shankweiler, D. (1970). Hemispheric specialization for speech perception. Journal of the Acoustical Society of America, 48, 579-594.

Vaid, J., & Genesee, F. (1980). Neuropsychological approaches to bilingualism: A critical review. Canadian Journal of Psychology, 34, 417-455.

Williams, L. (1977). The perception of stop consonant voicing by Spanish-English bilinguals. Perception & Psychophysics, 21, 289-297.

Williams, L. (1979). The modification of speech perception and production in second-language learning. Perception & Psychophysics, 26, 95-104.