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The Time Course of Acoustic/Phonemic Cue Integration in the Sensorineural Hearing-Impaired.

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The time course of acoustic/phonemic cue integration in the sensorineural hearing impaired

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The Time Course of Acoustic/Phonemic Cue Integration in the Sensorineural Hearing Impaired

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
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in

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by
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ABSTRACT

It has been documented that phonemic featural information is differentially distributed across time in the speech waveform. It is also known that listeners with sensorineural hearing impairment often make errors on phoneme identification tasks. However, there is little documentation available that describes how the hearing-impaired listener uses the various sources of phonemic information which are distributed in the speech waveform. In this investigation, a group of normal hearing listeners and a group of sensorineural hearing-impaired listeners (with and without the benefit of amplification) identified various consonant and vowel productions that had been systematically varied in duration. The consonants (presented in a /hɑCɑ́/ environment) and the vowels (presented in a /bVd/ environment) were truncated in steps to allow additional sequential segments of the original waveform to be presented. The results indicated that normal hearing listeners could extract more phonemic information from the earlier occurring portions of the stimulus waveforms, especially consonantal place information, than could the hearing-impaired listeners. For the hearing-impaired listeners in the unaided condition, percent correct identification for the consonant stimuli was lower than that for the normal hearing subjects, even for the full-duration stimuli, although the gap between impaired-unaided and

normal performance decreased as truncation times increased. For vowel stimuli, impaired-unaided performance appproached that of the normal hearing subjects for the full-duration stimuli, although significant performance gaps were apparent at shorter stimulus durations. The use of amplification did decrease the performance differences between the normal hearing listeners and the unaided hearing-impaired listeners. Yet, in many cases, even while using amplification, the hearing-impaired listeners could not make full use of the early-occurring feature information. The results are relevant to current models of normal speech perception which emphasize the need for the listener to make phonemic identifications as quickly as possible.

INTRODUCTION

The recognition of ongoing speech requires the listener to rapidly process a complex set of spectral and temporal cues in order to recognize phoneme, syllable, and word units. For any given phoneme in the speech sequence, multiple cues to its identity may be available. These cues will be distributed in time and may extend to preceding or following phonemic units (coarticulation). For example, cues to the identity of a given consonant may be found in the movement of the formants from the preceding vowel into that consonant and in the movement of the formants out of the consonant into the following vowel, along with those cues that can be found in the consonant itself. Recently described models of human speech perception (e.g., Marslen-Wilson & Welsh, 1978; McClelland & Elman, 1986) emphasize the need for the listener to (at some psychological level) make phonemic identifications as rapidly as possible by integrating whatever acoustic and linguistics cues are available. The listener monitors the signal for the minimally sufficient cue set that will uniquely define a given segment. Once a given segment (phoneme, syllable, or word) can be unambiguously identified, processing resources can be reallocated to the recognition of other segments.

A variety of investigations have demonstrated that normal hearing listeners only need a portion of the original waveform of a test phoneme in order to correctly

identify that phoneme. For example, Kuehn and Moll (1972) presented listeners with various consonants imbedded in a /VCV/ context, with various amounts of the end of the utterance deleted. These investigators reported that listeners could demonstrate above chance levels for consonant identification even for cases in which no stimulus energy was present after the vowel-consonant transition. These results indicated that significant consonant information must be available before the nominal beginning of the consonant. Tekieli and Cullinan (1979) used a similar truncation procedure to the one used by Kuehn and Moll (1972) to study the time course of emergence of various phonemic features in CV sylables. Tekieli and Cullinan (1979) observed that the proportion of the original stimulus waveform that was necessary to resolve phonemic information varied as a function of feature, with consonant place being resolved earlier than voicing and vowel advancement being resolved before vowel height. Thus, different portions of the stimulus waveform appear to bear different sorts of phonemic information.

It has been well documented that listeners with sensorineural hearing loss demonstrate a wide variety of deficiencies on spectral and temporal psychoacoustic tasks. It also has been well documented that these impaired listeners often have difficulty recognizing ongoing speech. However, this speech perception deficit can be explained only partially by analyzing abilities to recognize isolated

phonemes or words (see, for example, Rowland, Dirks, Dubno, & Bell, 1985). Furthermore, most detailed investigations into the speech perception skills of sensorineurally hearing-impaired listeners have treated the phoneme as a static, single event in time. The listener either correctly identifies the token or not. In other words, the available cue set either is or is not sufficient to unambiguously define the segment. Yet, there would seem to be value in determining how the emerging cues are integrated to lead to a phonemic identification (whether correct or not).

There are a variety of ways in which the relative salience of each of the available cues can be estimated. More specifically, attempts have been made to limit the available cue set to examine the effect of reducing the salience of or neutralizing certain cues. This goal has been achieved by reducing available spectral cues (via masking or filtering), providing a simplified acoustic waveform (via synthesized speech), or by reducing the duration of segments (via speeded or compressed speech) (See Dorman & Hannley, 1985, for a review). However, these cue-reduction studies have still treated the phoneme as a unitary event in time. Little is known of the time course over which the impaired listener integrates the available cues in order to make a phonemic identification. The normally-available cues in the ongoing speech waveform may

be unavailable or of limited salience given the hearing loss. More cues may need to be amassed before the segment is unambiguously defined. Therefore, the difficulty in processing on-going speech may not be due simply to an inability to identify each individual segment. Rather, the listener may not be able to extract information from the incoming stimulus at the same rate as normal listeners, as more processing capacity is being used to search for phonemic information.

The principal manner in which a hearing-impaired listener will attempt to overcome a speech perception deficit is through the use of a hearing aid. It is known that amplification can increase the proportion of words correctly understood (in certain situations), but it is not known precisely how this benefit is provided. It is generally assumed that amplification provides assistance by simply making more of the energy in speech audible (Pascoe, 1986; Skinner, 1987). Standard modern hearing aids are essentially amplifiers. With a few experimental exceptions, hearing aids do nothing more than increase the amplitude of the acoustic input to the ear in a frequency-specific manner. A variety of investigators (e.g., Danhauer, Hiller, & Edgerton, 1984; Levitt & Resnick, 1978; Maroonroge & Diefendorf, 1984) have demonstated that increases in the presentation level of speech material will allow hearing-impaired listeners to correctly identify a greater proportion of the test elements. Further, Skinner,

Karstaedt, and Miller (1982) and Skinner and Miller (1983) have demonstrated that speech recognition performance increases with increases in the theoretical amount of audible information. However, it should be stressed that audibility alone does not necessarily guarantee correct perception of speech information, as demonstrated by Turner and Robb, 1987. Given that we have a certain understanding of where in the acoustic waveform (Pickett, 1980) and where in the spectrum (Van Tasell, 1981) information for certain phonemic features can be found, it would seem that we could predict what effect amplification will have on speech understanding. Given the relatively weaker intensity of high-frequency speech energy (Van Tasell, 1981) and the flat to falling nature of the contours of most sensorineural hearing losses, there is a greater likelihood that higher frequency elements in the speech signal will be inaudible. It follows then that the use of a hearing aid would be expected to provide the most benefit in the perception of that phonemic information carried in the higher frequencies, such as consonant place and vowel tongue advancement. As this feature information may be differentially distributed in the stimulus waveform, the use of amplification might then be expected to alter the portion of the stimulus waveform from which the hearing-impaired listener can garner phonemic information.

This investigation represents a preliminary attempt to

describe the time course of phonemic identification in the sensorineural hearing-impaired listener. A group of normal hearing listeners and a group of sensorineural hearing-impaired listeners (with and without the benefit of amplification) attempted to identify various consonant and vowel productions that had been systematically varied in duration. The consonants (presented in a /hɑCɑ/ environment) and the vowels (presented in a /bVd/ environment) were truncated in steps to allow additional sequential segments of the original waveform to be presented. If phoneme perception is indeed a process of accumulating cues until a phonemic decision can be made, then it would be expected that the confusability of phonemes would decrease as more sequential segments from the acoustic waveform are available. Thus, examination of the response patterns at each successive duration allows for a description of the time course of phonemic identification in the two groups of listeners.

If sensorineural hearing-impaired listeners do require a greater proportion of the acoustic waveform before a phonemic identification can occur, then correct differentiation between possible phoneme options should occur at longer latencies for these listeners. This result would provide support for the notion that sensorineural hearing-impaired listeners suffer from an inability to extract phonemic information as quickly as normal listeners when trying to process ongoing speech.

REVIEW OF THE LITERATURE

Normal Perception

It has been long recognized that the cues to the identity of a particular phoneme are distributed in time. In fact, these cues often extend to preceding and following phonemes. In most cases, these cues are abundant, with phoneme identity predictable long before all available cues have occurred.

Ohman (1966) divided Swedish VCCV utterances at various points between the two consonants. When listeners were presented with either the truncated VC- or -CV segments, they were able to identify the missing consonant at above chance levels. Similarly, Ali, Gallagher, Goldstein, and Daniloff (1971) spliced away the final consonant from CVC and CVVC utterances. In the original utterances, these final consonants were specified as either being nasal or non-nasal. When listeners were presented with the truncated stimuli, they were able to identify the presence or absence of nasality in the missing consonant at above chance levels. Ali et al (1971) argued that the presence of cues to phoneme identity occurring before the nominal occurrence of the phoneme "lighten(s) the perceptual load" (p. 540) by allowing the listener to identify the phoneme as soon as possible. Winitz, Scheib, and Reeds (1971) excised the burst section of unvoiced stops produced in both word-initial and word-final

position. They reported that listeners, in some cases, could identify the adjacent vowel when presented with only the burst. Kuehn and Moll (1972) reported that, in VCV productions, vowel identity is apparent during the VC transition and consonant identity is apparent at the end of the CV transition. In fact, Strange, Edman, and Jenkins (1979) and Neary (1987) argued that because of the cues which are embedded in preceding and following consonants, vowels can be better identified when presented in a CVC context as opposed to when presented in isolation.

Phonemic information is apparently distributed across time during speech sound production. This spread of information across the stimulus waveform may take one of two different forms. First, a variety of individual cues may be place at different points in the stimulus waveform. For example, Raphael (1972) and Revoile, Pickett, Holden, and Talkin (1982) reported that a variety of different acoustic events can serve to indicate the presence or absence of voicing in syllable final consonants. Cullinan and Tekeili (1979) reported that certain vowel information (tongue advancement) is present in the aperiodic portion of preceding consonants. Best, Morongiello, and Robson (1981) identified both spectral and temporal cues that can be used to differentiate the presence or absence of a stop consonant between a fricative consonant and a vowel. Further, these authors argued that listeners integrate these different cues into an overall phonemic percept.

This finding is similar to the findings of Espinoza-Varas (1983), that listeners can integrate non-speech spectral and temporal cues into a single overall percept. Moreover, the results of Whalen (1984) would suggest that normal perception is dependent on the consistency of the pattern of various cues. Whalen (1984) took VC utterances and removed the vowel and VC transition. He then presented listeners with consonants preceded by either the appropriate or an inappropriate vowel and transition. Listeners demonstrated longer reaction times when attempting to identify the consonants preceded by mismatched vowel and transitional cues than those preceded by appropriate signals. Thus, phoneme identity can be marked by a variety of acoustic cues, with normal perception possibly being dependent on a consistent pattern of cues.

The distribution of phonemic cues across the stimulus waveform may also be characterized best as single, inherently time-varying, dynamic cues. In other words, certain cues may not be viewed appropriately as either temporal or spectral. Rather, certain cues may be best described as spectral changes over time. For example, Blandon (1985) argued that the perception of diphthongs is best interpreted as attention to the occurrence of spectral change over time (as opposed to a simple comparison of initial and final formant position). Neary and Assman

(1986) presented listeners with either repeated, identical segments excised from the early "nucleus" portions of vowels or a combination of excised segments from the nucleus and from the later "offglide" portions. Listeners were better able to identify the vowels in the latter condition. Neary and Assman (1986) interpreted the results as suggesting that vowel identification is dependent on monitoring the inherent spectral change during vowel production. Furui (1986) studied the perception of Japanese CVs at various truncations. Furui (1986) observed that percent correct identification of the CV segment increased monotonically with increases in preserved proportion of the original stimuli. However, the greatest increase in percent-correct occurred when a relatively short (40 ms or less) segment in which the greatest amount of spectral change occurred was included in the test stimulus. Furui's (1986) results suggest that phonemic perception is dependent on those sections of syllables in which spectral changes are occurring over time.

Blumstein and Stevens (1980) have argued for the presence of static, contextually invariant cues to phoneme identity. For example, they argue that stop consonant place is identified from a brief (10ms or less) segment of the burst release. However, follow-up work by Van Tasell, Hagen, Koblas, and Penner (1982), Kewley-Port, Pisoni, and Studdert-Kennedy (1983), and Walley and Carrell (1983) has indicated that the dynamic cues to consonant place may be

as effective if not more effective than the static cues.

As indicated previously, although a variety of cues may be available to mark phoneme identity, normal hearing listeners may not need all available cues. For example, historically, vowel steady-state formant frequencies have been assumed to provide the primary cues to identity. However, the work of Jenkins, Strange, and Edman (1983), Parker and Diehl (1984), and Strange, Jenkins, and Johnson (1983) has indicated that vowels can be identified based solely upon the transitions into and out of the steady-state portion. Wardup-Fruin (1985) demonstrated that when masking noise neutralizes the spectral cues to the presence or absence of voicing in syllable final consonants, the duration of the preceding vowel can serve as an adequate cue. Thus, the identity of speech sounds tends to be redundantly marked. However, even though normal hearing listeners do not need all available acoustic/phonemic cues, sensorineural hearing-impaired listeners may demonstrate difficulties making full use of the available cues.

Perception by the Hearing Impaired

There is abundant evidence that the cues in natural, unaltered speech are insufficient for many listeners with sensorineural hearing loss. These listeners simply cannot achieve the same level of phonemic resolution as achieved by normal hearing listeners.

Owens (1978), among others, reported that individuals with sensorineural hearing loss generally have significant difficulties on consonant discrimination tasks. Conversely, Owens, Talbott, and Schubert (1968) reported that, typically, vowel perception in quiet is unaffected in the hearing impaired. However, Nabelek and Dagenais (1986) and Nabelek and Letowski (1985) reported that vowel resolution is reduced when the stimuli are presented in noise and/or reverberation. Also, Leek, Dorman, and Summerfield (1987) and Turner and Van Tasell (1984) reported that hearing-impaired listeners show reduced performance on resolution of formant peaks in synthesized vowels.

Hearing-impaired listeners often show improved performance on speech perception tasks when certain modifications are made to the stimuli. For example, Picheny, Durlach, and Braida (1986) demonstrated consistent acoustic differences between "conversational" speech and "clear" speech. In a companion paper, it had been reported that sensorineural hearing-impaired listeners are better able to identify this "clear" speech (Picheny, Durlach, & Braida, 1985). The acoustic analysis revealed, for example, that "clear" speech elements tend to be prolonged, demonstrate greater consonant/vowel amplitude ratios, and demonstrate more distinct acoustic/phonemic contrasts. Similarly, Gordon-Salant (1987) reported that elderly

sensorineural hearing-impaired listeners show improved phonemic resolution when natural speech is computer-modified to increase the consonant/vowel ratios. Revoile, Holden-Pitt, Pickett, and Brandt (1986) reported that computer enhancement of the preceding-vowel length cue in natural speech can improve resolution of the voiced/voiceless distinction in syllable-final consonants for impaired listeners.

Other than showing generally decreased phonemic resolution only, hearing-impaired listeners may also use phonemic cues in a different manner than do normal hearing listeners. Recall that a variety of both temporal and spectral cues can mark the voiced/voiceless distinction in syllable-final consonants. A series of studies by Revoile and her colleagues (Revoile, et al, 1982; Revoile, Holden-Pitt, & Pickett, 1985; Revoile, Pickett, Holden-Pitt, Talkin, & Brandt, 1987) has indicated that impaired listeners tend to be more dependent upon temporal cues whereas normal listeners tend to be more dependent upon spectral cues. This finding is consistent with the conclusion of Dorman and Hannley (1985) that sensorineural hearing-impaired listeners show essentially normal temporal resolution but significantly reduced frequency resolution for nonspeech stimuli. Yet it should be noted that Ginzel, Pederson, Spliid, and Anderson (1982) have observed some disruptions in temporal cue usage for speech by elderly

hearing-impaired Danish listeners. Regardless, in general, the results of this area of investigation suggest that cue use in the hearing impaired may be differentially affected; certain acoustic/phonemic cues retain their saliency whereas others are of limited usefulness.

This suggestion of specific impairments in cue use is further supported by a variety of investigations into the patterns of consonantal errors demonstrated by impaired listeners. In terms of studies using real speech, Owens (1978), Owens and Schubert (1968), and Walden, Prosek, and Worthington (1975) all have indicated that the consonantal feature of place is the most often disrupted. The feature of voicing typically is resolved in a near-normal fashion. The feature of consonantal manner may show some disruptions, but usually is not as affected as the place feature. This hierarchy of feature resolution ordinarily is thought to be related to the fact that place information is most often located in the higher frequencies and is marked primarily by spectral events, with manner and voicing information transmitted in relatively lower frequency regions and are marked by both spectral and temporal events (Dorman & Hannley, 1985; Van Tasell, 1981).

It should be noted that Van Tasell et al (1982) have demonstrated that hearing-impaired listeners can be trained to use brief, static spectral cues to stop consonant place in a manner similar to that of normal listeners. However,

it also should be noted that the stimuli used in that investigation were presented in a three-alternative forced-choice format, as opposed to the "open-set" listening task which takes place in normal perception. Further, no information is avaiable on the training of place perception for other phonemes. Finally, Van Tasell et al (1982) do not report the relative time course of learning in the impaired versus normal listeners. It is unclear whether or not those impaired listeners required more training to achieve a similar level of performance. Dubno, Dirks, and Schaefer (1987) observed that some hearing-impaired listeners had difficulty in using short-term spectral cues to identify place for voiced stops. In that investigation, the subjects had only a brief training session and identification performance varied with changes in the duration of the test stimuli, audiometric contour, and vowel environment.

Although studies using real speech generally have demonstrated that the feature of place is more often disrupted than the features of manner or voicing, studies using synthesized speech may reveal more subtle disruptions along manner and voicing continua. When generating real-speech testing tokens, investigators have tended to use good, clear, prototypical productions. In other words, these materials usually consist of phoneme samples which are best differentiated from other phonemes. Recall in the findings of Picheny et al (1986) that conversational speech

does not show the same level of acoustic/phonemic differentiation as that in clear speech. Conversely, when using synthesized speech, investigators most often have been concerned with performance near phoneme boundaries. If the acoustic boundaries between phonemes are not sharp and clearly differentiated, "conversational-style" speech tokens which are not prototypical may fall in the region near boundaries in which phonemic confusions can occur.

There have been a variety of studies using synthesized speech with hearing-impaired listeners. In general, these investigations have confirmed the finding with real speech that place contrasts are the most difficult for impaired listeners. However, these studies also have indicated that, for some listeners, considerable boundary disruptions can occur along manner and/or voicing continua. For example, Godfrey and Millay (1980) reported that sensorineural hearing-impaired listeners show no difficulty resolving synthesized steady-state vowels; however, they demonstrate some boundary disruptions along the stop/glide manner continuum and considerable disruptions along the stop consonant place continuum. Van de Grift Turek, Dorman, Franks, and Summerfield (1980) and Walden, Montgomery, and Prosek (1986) have confirmed the finding of boundary disruptions along the place continuum for impaired listeners. Dorman, Marton, Hannley, and Lindholm (1985) also have confirmed the finding of place difficulties; however, they reported that impaired listeners demonstrate

normal use of a temporal cue to consonant manner. Johnson, Whaley, and Dorman (1984) and Parady, Dorman, Whaley, and Raphael (1981) reported that disruptions can occur along the voicing continuum, yet these disruptions typically occur only in listeners with severe or profound sensorineural hearing loss. Thus, in some cases, manner and voicing features may show some disruptions.

It is important to establish whether the speech perception difficulties demonstrated by impaired listeners are simply a result of the reduction in audibility brought about by the threshold impairment, or if further, suprathreshold processing deficits are also at work. The work of Bilger and Wang (1976) suggested that the patterns of errors demonstrated by sensorineural hearing-impaired listeners can be explained by audiogram shape. However, the work of Pavlovic (1984) and Kamm, Dirks, and Bell (1985) has indicated that speech processing difficulties of impaired listeners cannot be completely accounted for by the reduced audibility of the long-term spectral characteristics of speech. A similar conclusion was reached by Turner and Robb (1987) when they examined the audibility of the short-term spectral characteristics of speech stimuli.

Given that it appears that sensorineural hearing-impaired listeners demonstrate a hierarchical pattern in

difficulties for feature resolution, it would be instructive to view this hierarchy in relation to the time course of the sequential emergence of these cues in ongoing speech. Both Kuehn and Moll (1972) and Tekieli and Cullinan (1979) have studied the emergence of consonant and vowel features for normal hearing listeners in real speech. In both studies, various amounts of the final portions of test syllables were removed and confusions were studied for the truncated stimuli. For consonant stimuli, place information appears to be available first, followed by manner and then voicing information. For vowels, tongue advancement is revealed first, followed by information concerning tongue height and, finally, tenseness. Grimm (1966) used a converse procedure in which he progressively eliminated portions of the beginning of CV syllables. This procedure allows for an examination of the relative time course of the termination of feature information. Grimm (1966) reported that, for consonants, manner information finishes first, followed by voicing and then place information. For hearing-impaired listeners, the implication of these truncation studies is that, although place information is distributed over the greatest amount of time (available first and persists the longest), this information still may not be sufficient.

For normal hearing listeners, we have some information as to how phonemic cues are integrated over time to form a single phonemic percept. We have less

information as to how this integration occurs for hearing-impaired listeners. However, evaluating the specific details of this integration would be consistent with several of the currently discussed models of speech perception (e.g., Elman & McClelland, 1984; McClelland & Elman, 1986; Marslen-Wilson & Welsh, 1978). These models share the common principle that a listener uses whatever information is available to achieve an identification of a speech segment as soon as possible. In other words, it would seem that a listener amasses acoustic and linguistic cues until the identity of a given speech segment is apparent. Recall the assertion of Ali et al (1971) that the presence of backward coarticulation "lightens the perceptual load" by providing phonemic cues early on. It would thus be predicted that if a listener cannot integrate temporally-distributed acoustic cues in a normal fashion, speech perception would be disrupted. For a given speech sound, the listener may have to wait for the occurrence of further acoustic cues or may become more dependent on "top-down" cues. To the extent that this redistribution of cue-importance falls short of providing the same amount of information with the same amount of processing effort, perception thus would be impaired.

METHOD

Subjects

Two groups of subjects were included in the investigation: Three young adult (20-27 years old) listeners with normal hearing and four young adult (20-35 years old) listeners with longstanding, bilaterally symmetrical sensorineural hearing loss of presumed cochlear origin. All three normal hearing listeners (N1, N2, N3) passed a pure-tone screening test at 10 dB HL for the octave frequencies from 250 to 8000 Hz in both ears. For the hearing-impaired listeners, the cochlear nature of the hearing losses was confirmed by bone conduction thresholds being within 10 dB of air conduction thresholds, negative reports of unilateral tinnitus or recent marked changes in hearing, and the absence of significant reflex decay. N1 and N2 were students in a clinical training program in Communication Disorders, with neither subject having any formal experimental listening experience. N3 (the author) was a graduate student in Communication Disorders with extensive experimental listening experience. One of the hearing-impaired listeners (HI1) had a mild-to-moderate loss and had chosen not to use amplification due to a peceived lack of need. The three other hearing-impaired listeners (HI2, HI3, HI4) were regular users of binaural amplification. Table 1 provides the audiometric data for the hearing-impaired listeners. Table 2 provides the amount of binaural functional gain achieved by the three

hearing aid users. These levels of functional gain were established by comparing unaided vs aided soundfield thresholds for 5% frequency modulated tones. During soundfield testing, the hearing aid users set their volume control wheels to make running speech at 50 dB HL clear and comfortable to listen to. Table 2 also indicates the amount of spectral enhancement inserted into the playback system during testing for HI1 (who did not use amplification) so as to replicate the use of binaural hearing aids. Table 3 provides the unaided and aided word recognition scores for the hearing- impaired subjects (using CID W22s presented at 50 dB HL). The hearing-impaired subjects were recruited from client files of the LSU Speech and Hearing Clinic. All subjects were paid for their participation.

Materials

The stimuli were comprised of natural speech tokens produced by one adult male talker with General American Dialect. A reel-to-reel tape recording (Nagra 4.2 recorder with a Shure SM7 microphone) was made of the talker producing fifteen repetitions of ten consonants (/b,p,d,t,v,f,z,s,m,n/) in a /hɑCɑ/ environment and fifteen repetitions of six vowels (/i,e,ɑ,u,o,ae/) in a /bVd/ environment. The talker produced the /hɑCɑ/ utterances with the stress on the first syllable but with a fully-produced (non-neutralized) second vowel. The ten consonants represent contrasts in the dimensions of manner,

place, and voicing. The six vowels represent contrasts in the dimensions of tongue height and tongue advancement. Tables 4 and 5 provide more details concerning the specific contrasts represented. These stimuli were selected not to represent all available consonants and vowels, but rather to provide a simple and straightfoward set of contrasts. Also, all ten consonants are represented in an identical manner both orthographically and phonetically, eliminating the need to train the listeners in phonetic transcription. The vowels also can be represented orthographically in a straightfoward manner.

The recorded utterances were digitized using a MetraByte Analog-to-Digital converter at a 10 kHz sampling rate (4.8 kHz low-pass filtering) and stored on an IBM AT microcomputer. Any utterances with obvious mispronunciations were eliminated. The remaining utterances were analyzed using the McIntosh MacSpeech Lab waveform, spectrogram, and fundamental frequency displays. For the /hɑCɑ/ utterances, these displays were used in order to determine: (1)the fundamental frequency for the vowels, and (2)the duration of the first vowel. For the /bVd/ utterances, these displays were used in order to determine: (1)the fundamental frequency for the vowel, and (2)the voice-onset time for the /b/.

Out of the original set of utterances, three

productions of each /hɑCɑ/ were chosen such that the fundamental frequency for the vowels and the duration for the first vowel all demonstrated midrange values for the set of utterances using that test consonant (i.e., the midrange values for the productions using one test consonant were not necessarily the same as those for some other test consonant). This procedure was used so to eliminate any extraneous cues based on an unusual production in the vowels and to preserve any consistent cue to consonant identity that may be contained in the vowels. In a similar vein, for the /bVd/ utterances, three productions were chosen for each test vowel such that the fundamental frequency for the vowel and the voice-onset time for the /b/ both demonstrated midrange values.

The productions in this group of three examples of each test construction were presented auditorily to three professionals in Communication Disorders. For each production, the listener was presented with a phonetic transcription of the target construction. The listener was required to determine if "this production is an accurate, well-formed example of this construction". The listener was required to respond either "yes" or "no". The final group of test productions was comprised of one example of each construction which received a "yes" vote from all three judges. If more than one example received three "yes" votes, one of those examples was chosen at random to be the final test utterance. Therefore, the final group of

consonant test stimuli included one production each of /b,p,d,t,v,f,z,s,m,n/ in a /hɑCɑ/ environment, demonstrating midrange values on a variety of acoustic dimensions and being consistently judged as an accurate and well-formed example of that consonant. The final group of vowel test stimuli included one production each of /i,e,ɑ,u,o,ae/ in a /bVd/ environment, demonstrating midrange values on a variety of acoustic dimensions and being consistently judged as an accurate and well-formed example of that vowel. The relevant acoustic specifications of the final set of test stimuli can be found in Appendix A.

For the final set of /hɑCɑ/ productions, a locally-constructed digital waveform editting program was used to equalize the duration of the /h/ across the ten productions. The waveform editor was used to delete portions from the middle of the /h/ in order to achieve a target duration of 65 ms for the /h/ in each of the ten productions. The waveform was cut only at zero-axis crossings in an attempt to reduce the occurrence of audible transients. It was reasoned that the duration of the /h/ was not expected to act as a normally-occurring cue to the identity of the test consonant. However, it was possible that variations in the duration of the /h/ could act as a cue that could be learned for this set of stimuli. Therefore, this potential non-phonemically-meaningful cue was eliminated.

The waveform editting program was used to identify two relevant landmarks on each /hɑCɑ/ production: (1)the closure point on the test consonant, and (2)the release point on the test consonant. Based upon these identified landmarks, nine different durations were determined for each consonant construction. Each duration started at the normally-occurring begining of the /hɑCɑ/ production. The truncation point was set to fall at the following nine points: 50 ms before the closure (C-50), 10 ms before the closure (C-10), 10 ms after the closure (C+10), 25 ms after the closure (C+25), at the midpoint between the closure and release (Mdpt), 10 ms before the release (R-10), 10 ms after the release (R+10), 50 ms after the release (R+50), and after the normaly-occurring end of the utterance (Full). Figure 1 provides the waveform of the full-duration /hɑbɑ/ with the various truncation points indicated. Appendix A provides the closure-to- release duration for all of the consonant stimuli.

The waveform editting program was used to identify one landmark on the waveform of each test vowel production: the release point of the /b/. Based on this landmark, six durations were established. All six durations started at the normally occurring beginning of the utterance. The truncation point was set to occur at the following six points: 25 ms before the release (R-25), 10 ms before the

release (R-10), 10 ms after the release (R+10), 25 ms after the release (R+25), 100 ms after the release (R+100), and after the normally-occurring end of the utterance (Full). Figure 2 provides the waveform for the full-duration /bid/ stimulus with the various truncations indicated. Appendix A provides the closure duration for the /b/ for each of the vowel stimuli.

The truncation points for both the consonant and vowel stimuli were chosen based on pilot data from two normal hearing listeners in order to provide a range in performance from chance identification to 100% identification. With ten test consonants and nine truncation points, there was a total of 90 consonantal stimuli. With six test vowels and six truncation points, there were 36 vowel stimuli.

Instrumentation

The ten full-duration consonant stimuli and the six full-duration vowel stimuli were stored digitally on the IBM AT microcomputer. At the time of playback, a truncated stimulus was produced by outputting only that portion of the full-duration file up to the target truncation point. The control program made the actual truncation at the nearest zero axis crossing following the target truncation point (assuming the target truncation point was not a zero axis crossing). Across all the stimuli used, the actual truncation point fell within 3 ms of the target truncation

point. This technique was used in order to minimize audible transients. Auditory monitoring of the truncated stimuli indicated that this truncation procedure was sufficient to eliminate any audible transients.

The stimuli were ouput via a Metrabyte Digital-to-Analog converter at a 10 kHz rate. The analog waveform was low-pass filtered at 4.8kHz via a Wavetek-Rockland 752A brickwall filter. The output of the brickwall filter was fed to a Bruel & Kjaer 1612 one-third octave band multifilter. The output of the multifilter was fed through a clinical audiometer (Madsen OB 822), soundfield amplifier (McIntosh 250), and finally through a soundfield speaker (Grason-Stadler 0162). The settings on the multifilter were adjusted to insure that the playback system (up to the speaker) was flat within 2 dB from .1 through 4.8kHz.

During testing, the full-duration stimuli were presented at a target level of 70 dB peak SPL measured 2 m from the speaker (at the point of the subject's head). During the process of stimuli selection, no specific steps were taken to control for stimulus amplitude. However, all sixteen of the full-duration test stimuli fell within a 3 dB range of peak intensity. Therefore, the actual full-duration stimuli fell within a ± 1.5 dB range around the target level of 70 dB SPL. The same amplitude settings on all the instrumentation were used for the full-duration

stimuli as for all the truncated stimuli. Therefore, for many of the shortest stimuli (those without significant vowel energy), the actual peak intensity was less than 70 dB SPL. The noise floor of the combination of the soundbooth and playback system (while outputting empty stimulus files) was measured to be <30 dBA.

Procedure

The subjects were tested in a series of one-hour experimental sessions. During the first test session, the traditional audiometric measures (Tables 1, 2, & 3) were obtained. During any subsequent session in which amplification was to be used, the hearing aids were adjusted to provide the same levels of functional gain indicated in Table 2.

The basic experimental task required of the subject was closed-set identification. During consonant testing, the subject was seated in front of a computer keyboard and monitor. During a trial, the word "ready" would appear on the screen for approximately 500 ms, followed by the auditory stimulus, followed by the appearance of the ten numbered response alternatives on the screen ("1-haba 2-hapa 3-hada 4-hata 5-hava 6-hafa 7-haza 8-hasa 9-hama 10-hana"). The subject was instructed to press the key corresponding to the number of his/her response. Once a response was indicated and recorded by the computer, a 1000

ms inter-trial period occurred before the next trial began. During vowel testing, the procedure was the same except that only six numbered response alternatives were shown on the screen ("1-beed 2-bade 3-bod 4-bood 5-bode 6-bad").

A test run consisted of random presentation of each of the 90 consonant stimuli or each of the 36 vowel stimuli. The normal hearing subjects completed one practice run and 10 such test runs for the consonants, and one practice run and 10 test runs for the vowel stimuli. For both consonant and vowel stimuli, the hearing-impaired subjects completed one practice run and ten test runs while aided and one practice run and ten test runs while unaided. A consonant test run typically took approximately 10 minutes to complete and a vowel run took aproximately 4 minutes to complete.

The order of aided vs unaided testing and consonant vs vowel testing was randomly varied from subject to subject. All ten test runs were completed in one listening condition before testing in another condition began.

RESULTS

The percent correct phoneme identification was tallied for each subject for each test phoneme at each truncation point. These results can be found in Appendix B. (Incorrect responses were also retained and will be discussed below.) The data were inspected and analyzed in order to answer the following three questions:

(1)Compared to normal listeners, do hearing-impaired subjects require a greater proportion of the stimulus waveform in order to fully resolve phoneme identity?

(2)Does the presence of amplification reduce the proportion of the stimulus necessary to make a correct identification?

(3)If hearing-impaired listeners do require a greater proportion of the stimulus waveform, does the required increase vary by distinctive feature?

(4)Are there consistent differences in the types of errors made between and within subject groups?

Subject Groupings

A preliminary question which needs to be addressed is whether the performance of the various subjects within each group was homogeneous enough for group means to be used in analysis. More specifically, it is conceivable that the performance of N3, as the only experienced listener, might be expected to depart from that of N1 and N2. To evaluate this possibility, Pearson product-moment correlation

coefficients were calculated for all pairwise comparisons of percent correct scores within the group of normal listeners for both the consonant and vowel stimuli. These correlation coefficients can be found in Table 6. As can be seen, all pairwise comparisons demonstrated positive and significant ($p<.0001$) correlation coefficients. Those correlations involving N3 were not markedly reduced as compared to that of N1 and N2. Therefore, it was concluded that the performance of N3 was not significantly different from that of the other two normal hearing listeners. Thus, for the remainder of the analyses, group mean performance will be used for the normal listener data.

In terms of the hearing-impaired listeners, pairwise correlation coefficients were calculated between subjects for the consonant stimuli and the vowel stimuli in both the unaided and aided condition. (Note that HI4 did not complete consonant testing in the unaided condition.) These results can also be found in Table 6. As can be seen, the correlation coefficients between HI1, HI2, and HI3 are positive and significant ($p<.0001$). Those comparisons involving HI4 are nonsignificant ($p>.0001$) in the aided consonant condition but are significant in all but one case in the two vowel conditions.

Given the absence of unaided consonant results for HI4 and the significant correlations between the performance of HI1, HI2, and HI3, percent correct performance was averaged

over HI1, HI2, and HI3 for both the consonant and vowel stimuli in both the unaided and aided conditions. Although HI4 did complete testing in the aided consonant and two vowel conditions, these data were not included when calculating mean performance so that comparisons could be made between vowel vs consoant and aided vs unaided conditions for the same group of subjects. The performance of HI4 will be considered in a separate analysis below.

Consonant Results

The percent correct performance for each of the subject groups at each truncation point averaged over the ten consonants can be found in Figure 3. As can be seen, performance is typically better at the longer stimulus durations. The normal hearing subjects demonstrate the best performance and the impaired-unaided listeners performed the poorest. The principal question being addressed in this investigation is whether the groups differ as to how much of the test syllable needs to be presented before a correct identification can be made. In Figure 3, a single asterisk is used to mark the truncation point at which performance rose above chance (.1) for each group ($p<.05$). As can be seen, the performance of the normal and impaired-aided group rises above chance at the C-10 cutpoint. In contrast, the impaired-unaided group does not rise above chance performance until the C+10 cutpoint. Also in Figure 3, a double asterisk is used to

indicate the earliest truncation point at which performance was not significantly different from performance for the full-duration stimuli ($p>.05$). This point will be refered to as the "asymptote point". As can be seen, performance for the normal and impaired-aided groups asymptotes by the MDPT truncation point, whereas performance for the impaired-unaided group does not asymptote until the R-10 truncation point.

Table 7 provides the percent correct for each consonant averaged across the subjects within each group. Inspection of the data in Table 7 indicates that the impaired-unaided and, to a lesser extent, the impaired-aided groups demonstrate more difficulty for the unvoiced consonants, as resolution occurs at later truncation times and asymptotic performance is reduced, at times, from 100%. Note that for most phonemes identification performance reaches essentially 100% by full-duration, except for /p/ for both impaired groups and /d/ and /t/ for the impaired-unaided condition. More specifically, certain phonemes for certain combinations of subject groups appeared to be resolved at later truncation times than the other phonemes. For example, /p/ and /f/ appeared to be more difficult to resolve for the impaired groups (unaided and aided) whereas /s/ and /t/ appeared to be more difficult for the normal and impaired-unaided groups.

The error rates for the individual phonemes should be interpreted in light of any possible response biases on the part of the subjects. If a subject had no information as to phoneme identity and were responding at random, then each of the ten response alternatives should be chosen at a rate of .1. Also, if a stimulus is perfectly intelligible, then, again, the selection probability should be .1 since all phonemes were presented an equal number of times. Table 8 provides the selection probabilities for each of the consonant response alternatives averaged across the 10 test consonants and across the first four truncation times. The first four truncation times were used since the majority of errors for all three groups were made before the fifth truncation time. As can be seen, all three groups demonstrated a selection probability for /p/ which was significantly ($p<.05$) greater than the expected, unbiased rate of .1. The normal and impaired-unaided groups also demonstrated a significantly increased selection rate for /t/. Therefore, the percent correct performance for /p/ and /t/ reflected in Table 7 may overestimate the true identifiability of those consonants at the early truncation times because of the subjects' tendency to use voiceless stops as response alternatives.

Vowel Results

The percent correct performance for each subject group at each truncation point averaged over the six vowel stimuli are presented in Figure 4. Again, it is evident

that performance increases as more of the stimulus waveform is presented. However, except at R+10 and R+25, there are few apparent differences between the performance of the three groups. At the R+10 truncation point, the normal group demonstrated higher identification performance. At R+25, both the normal and impaired-aided groups demonstrated higher performance. The point at which performance rises above chance (.167) ($p<.05$) and the asymptote point ($p>.05$) were determined for the data of each of the three groups separately. These points are indicated on Figure 4 by a single asterisk and a double astrerisk, respectively. For the normal and impaired-aided groups, performance rises above chance by R+10 and has asymptoted by R+25. Conversely, for impaired-unaided group, performance rises above chance at R+25 and asymptotes by R+100.

The percent correct for each of the individual vowels averaged across subjects within each group are presented in Table 9. Review of this data indicates earlier resolution of /u/ for all groups and relatively later resolution of /e/ and /o/.

The selection probabilities for the vowel response alternatives averaged across the 6 test vowels and across the first three truncation times are provided in Table 10. The expected, unbiased selection rate is .167. All three groups demonstrated a significant ($p<.05$) bias to select

the /u/ alternative.

Feature Resolution-Consonants

Given that it is known that different phonemic cues occur at different points in the stimulus waveform, an attempt was made to describe the identifiability of different distinctive features at the various truncation points. During data collection, incorrect subject response were recorded along with correct reponses (these data can be found in Appendix C). Each response was then scored as either correct or incorrect on the features of place, manner, and voicing. For example, if the test stimuli was /z/ and the subject responded /t/, the response would have been scored as correct for place (both /z/ and /t/ are alveolar) but incorrect for manner and voicing (/z/ is a voiced fricative and /t/ is an unvoiced stop).

Figure 5 presents the results of this analysis for the feature of place, Figure 6 for the feature of manner, and Figure 7 for the feature of voicing. Examination of Figure 5 reveals that place is easily resolved by the normal hearing listeners by C-10, whereas the impaired-unaided and, to a lesser extent, the impaired-aided groups need a much greater proportion of the stimulus in order to fully resolve the place feature. Conversely, for the manner and voicing features, performance between the three groups is similar at all truncation points. Feature resolution for

manner and voicing occurs at approximately the same point in the stimulus waveform, with these features being resolved later than place for the normal hearing subjects, but earlier than place for the hearing-impaired subjects.

An analysis of variance (ANOVA) procedure using a Split-Plot design was performed on the data for each feature separately. Truncation point was modeled as a within subject effect and Group was modeled as a between subject effect. The results for the place resolution data indicate significant ($p<.05$) Group ($f=21.44$, $df=2,6$), Truncation ($f=50.71$, $df=8,48$), and Group x Truncation ($f=2.79$, $df=16,48$) effects. The results for the manner resolution data indicate a significant ($p<.05$) Truncation ($f=27.58$, $df=8,48$) effect. The results for the voicing resolution data indicate a significant ($p<.05$) Truncation ($f=73.46$, $df=8,48$) effect.

The differential resolution of place vs manner and voicing can be illustrated with examples from specific subjects. Figure 8 provides the responses of N3 to the /v/ stimuli at each truncation point. Figure 9 provides the responses of HI2, while unaided, to these same stimuli. Figure 10 provides the reponses of HI2 to the /v/ stimuli while aided. In these Figures, the percentage of selection for each of the response alternatives is indicated. Phonemes chosen at a rate of 0% are not indicated.

Examination of Figure 8 reveals that, for the shortest stimuli, N3 provided responses which were in error for place, manner, and voicing. However, by the second truncation point, all responses were correct in terms of place (/p/, /v/, & /b/ are all labials), with only manner and voicing errors occurring. By the third truncation point, /v/ appears to be essentially fully resolved. These responses can be contrasted to those for HI2 while unaided, as shown in Figure 9. Note that place errors occur frequently through the third truncation point (/t/, /d/, & /z/ are alveolar consonants), with other miscellaneous errors occurring at most truncation times. Finally, with the addition of amplification for HI2 (Figure 10), significant place errors occur only through the second truncation point, with /v/ essentially fully resolved by the third truncation point. Thus, when comparing HI2 to N3 for the /v/ stimuli, the hearing impairment appears to delay the resolution of the correct response, yet the use of amplification does reduce this performance deficit to a certain degree.

Table 11 provides the correlations for consonant feature resolution between the subjects within each test group. If two subjects were making similar errors, then it would be expected that significant correlation would exist between their resolution of all three features. Conversely, if the subjects were making different types of errors, the correlations for one or more of the features

would be reduced. As can be seen in Table 11, for the normal hearing listeners and HI1, HI2, and HI3 while aided, all pairwise correlations are significant ($p<.0001$) for all three features. For HI1, HI2, and HI3 in the unaided condition, all pairwise correlations for manner and voicing are significant ($p<.0001$), but the correlations for place resolution are non-significant ($p>.0001$).

The types of errors made for each feature can be further delineated. In other words, a consonant place error can be made either by substituting a labial for an alveolar or by substituting an alveolar for a labial. Table 12 provides the occurrence percentages (based upon the total number of occurrences of the target phonemes) for each type of place error, averaged over the first four truncation times. As can be seen, all three groups and HI4 demonstrated a higher percentage of labial-for-alveolar errors than vice versa. ANOVA testing (using a Split-Plot model) revealed both significant ($p<.05$) group and phoneme-type errors. Table 13 provides the occurrence percentages for the consonant manner error types. ANOVA results indicate a significant ($p<.05$) error-type effect, with follow-up Tukey comparisons indicating both the stop-for-fricative error rate and the stop-for-nasal error rate to be significantly ($p<.05$) greater than all other error rates. Table 14 provides the voicing error rates. ANOVA results revealed a significant ($p<.05$) error-type effect,

as the voiceless-for-voiced error rate was greater than the voiced-for-voiceless error rate. In general then, for all three groups, when errors occurred at the early truncation times, they tended to favor the selection of consonants which were labial, stopped, and/or voiceless.

Feature Resolution-Vowels

Incorrect responses were also retained during vowel testing (see Appendix C). These responses were analyzed in terms of resolution of the features of tongue advancement and tongue height. The results are presented in Figure 12 (tongue advancement) and Figure 13 (tongue height). As can be seen, performance across all three groups is rather similar for both features. Both features are essentially fully resolved by the same truncation point, R+25. The only differences between groups appears to be that at R+10, where the normal hearing subjects are better able to resolve both tongue advancement and tongue height.

ANOVAs were also performed for the vowel feature resolution data. The results for the tongue advancement data indicate a significant ($p<.05$) Truncation ($f=106$, $df=5,30$) effect. The results for the tongue height data also indicate a significant ($p<.05$) Truncation ($f=191.7$, $df=5,30$) effect.

Figures 13, 14, and 15 provide examples of the performance of specific subjects. Figure 13 provides the

responses of N1 to the /ɑ/ stimuli at each truncation point. Errors in terms of both tongue advancement and tongue height occur at the first two truncation points. By the third truncation point, /ɑ/ identity appears to be fully resolved. For contrast, Figure 14 provides the responses to the /ɑ/ stimuli for HI1 while unaided. As can be seen, /ɑ/ identity is not fully resolved until the fourth truncation point, with both tongue advancement and tongue height errors occuring at the first three truncation points. The performance of HI1, while aided, is reflected in Figure 15. The use of amplification appears to allow HI1 to resolve /ɑ/ identity by the third truncation point, the resolution point for N1. Thus, overall, vowel performance for the impaired listeners, whether aided or unaided, was not markedly worse than normal performance, with both vowel features resolved in a similar fashion.

Table 15 provides the correlations for vowel feature resolution between the subjects within each test group. For the normal hearing listeners and HI1, HI2, and HI3 aided, all pairwise correlations for both tongue advancement and tongue height are significant ($p<.0001$), suggesting that these subjects (within their respective groups) demonstrated similar patterns of feature resolution. For the unaided hearing-impaired subjects, the vowel height pairwise comparisons are significnt ($p<.0001$), yet the tongue advancement correlations are non-significant

(p>.0001), suggesting differing abilities for resolution of tongue advancement.

Vowel errors were also specifically classified. Table 16 provides the occurrence rates for tongue advancement errors. The normal subjects and the impaired-unaided subjects demonstated a greater tendency to make back-for-front errors, while the impaired-aided listeners made more front-for-back errors. ANOVA (Split-plot) results indicated both significant ($p<.05$) error-type and group X error-type effects. Table 17 provides the tongue height error rates. ANOVA results supported a significant ($p<.05$) error-type effect, with follow-up Tukey comparisons indicating that the high-for-low and high-for-mid rates were both significantly ($p<.05$) greater than the low-for-high and mid-for-high rates.

HI4 Performance

As indicated previously, HI4 did not complete testing for the consonant stimuli. This subject reported extreme difficulty during aided consonant testing. Pretesting using just full-duration consonant stimuli revealed essentially random identification performance. Recall that given this lack of data, the results from HI4 were not used when calculating group mean performance for the hearing-impaired listeners. Examination of the responses of HI4 reveals unique error patterns.

In terms of consonant performance, Table 18 provides the percent correct at each truncation point for HI4, while aided, for overall performance and for the resolution of place, manner, and voicing. These results are averaged over the ten test consonants. As can be seen, overall consonant identification performance never rises above 33% correct. This can be contrasted to performance levels of approximately 80% or better for the last five truncation points for the group mean in the impaired-aided condition. Thus, HI4 had extreme difficulty in resolving phoneme identity. HI4 was best at resolving place information, even at the shorter truncation points (chance performance being .5). Errors tended to be in terms of manner and, to a lesser extent, voicing. Note that at, for example, the C+25 truncation point, place was identified at 75% correct, whereas manner was identified at 46% correct and voicing at 68% correct.

The error patterns for HI4 can be illustrated by examining the responses provided by HI4 to the /v/ phoneme, as reflected in Figure 16. Note that /v/ reponses rise above 30% correct at only two truncation points (R+10 & R+50). Error responses are spread over a relatively high number of alternative phonemes, with manner errors being most numerous. These responses can be compared to those for HI2 in the aided condition, as reflected in Figure 10. Recall that for HI2, /v/ was essentially fully resolved by

the third truncation point.

Vowel identification was also somewhat reduced for HI4 compared to the other hearing-impaired subjects. Table 19 provides overall vowel identification performance and feature resolution for HI4 in both the unaided and aided condition. In the unaided condition, vowel identification was poor until the R+100 truncation point, with neither tongue advancement resolution nor tongue height resolution rising above chance performance until the R+25 truncation point. In the aided condition, overall vowel identification and feature resolution are essentially random until the R+25 truncation point, at which performance approaches that of the other hearing-impaired subjects (see Figures 4, 6, & 7 for comparisons).

Figure 17 provides a specific example of the reponses demonstrated by HI4. When presented with the /ɑ/ stimuli while aided, HI4 demonstrated a high proportion of errors in terms of both tongue advancement and tongue height until the R+25 truncation point. At that point, /ɑ/ identity begins to be resolved. These responses can be compared to those of HI1 while aided, as reflected in Figure 15. Notice that /ɑ/ resolution occurs earlier and is more consistent for HI1.

The correlations for feature resolution for HI4 compared to the other hearing-impaired listeners can be

found in Table 11 (consonants) and Table 15 (vowels). One of the nine pairwise comparisons for the consonant features and six of the twelve comparisons for the vowel features were significant ($p<.0001$). The presence of non-significant correlations for many of the pairwise comparisons indicate that HI4 demonstrated unique patterns of feature resolution ability as compared to the other hearing-impaired subjects. Review of the specific types of errors made by HI4 (Tables 12, 13, 14, 16, & 17) revealed that this subject, in some cases, made the same sorts of errors as did the other listeners. For example, HI4 made relatively high numbers of voiceless-for-voiced consonant substitutions. However, in many cases, the errors made by HI4 were unlike those made by the other subjects, such as relatively higher rates for nasal-for-fricative consonant errors or low-for-mid vowel errors.

DISCUSSION

Normal Results

Before reviewing the performance of the hearing-impaired subjects, it is important to compare the present results from the normal hearing listeners to the results of previous investigations. As can be seen in Figure 3, the normal hearing subjects demonstrated above chance performance 10 ms before the closure point and high consonant recognition performance by the C+25 truncation point, with performance asymptoting at near perfect performance by the midpoint of the consonant closure portion. Using a similar procedure to that used here, Kuehn and Moll (1972) observed that normal hearing listeners demonstrated above chance performace at a point corresponding to the consonant closure point used in this investigation and asymtotic performance by the time of consonant release. (They did not use any truncation points between the closure and release.) Therefore, for both the present investigation and that by Keuhn and Moll (1972), enough information for correct identification of consonant identity must be present during the closure portion.

In contrast, the listeners in the investigations by Tekieli and Cullinan (1979) and Furui (1986) did not typically demonstrate asymptotic performance until some time after the release of the consonant. For example, Tekieli and Cullinan (1979) report that asymptotic

performance was reached at approximately 30 to 40 ms after the consonant release. Similarly, Furui (1986) claims that the essential information for consonant identification falls in a time-window as short as 50 ms (depending on the consonant) around the point of maximal spectral transition, which typically occurs at the point of consonantal release.

The most likely reason for the difference in findings for the present investigation and that by Kuehn and Moll (1972), on the one hand, and for Tekieli and Cullinan (1979) and Furui (1986), on the other, is the phonemic environment of the test materials. The present investigation presented the test consonants in an intervocalic construction (/hɑCd). Kuehn and Moll (1972) also presented their test consonants in an intervocalic environment, as their CV syllables were immediately preceded by the carrier phrase, "had a /CV/". In contrast, both Tekieli and Cullinan (1979) and Furui (1986) presented isolated CVs. Thus, listeners appear to be able to garner consonantal information from the preceding vowel and vowel-consonant transition. If this information is not available, the consonant must be released before consonant identity can be fully resolved.

As far as feature resolution is concerned, the normal hearing listeners in the present investigation could identify consonant place before consonantal release and at

least 35 ms before they could identify manner and voicing (Figures 5, 6, & 7). It is assumed that the listeners could make their place identifications based upon information contained in the vowel-consonant transition. Conversely, these listeners had to wait until some point in the nominal production of the consonant before manner and voicing could be resolved. Similarly, the listeners in the Tekieli and Cullinan (1979) investigation could make place identifications before they could make voicing identifications.

Concerning performance for the vowel stimuli, the normal hearing listeners in the present investigation demonstrated above chance performance by 10 ms after the consonant release and asymptotic performance by 25 ms after the consonant release. These results are in good agreement with those of Tekieli and Cullinan (1979), who observed asymptotic performane by 20 to 30 ms after release. The listeners in the Tekieli and Cuillinan (1979) investigation demonstrated resolution for the feature of tongue advancement at 20 ms followed by resolution of tongue height by 30 ms. In the present investigation, the listeners did not demonstrate a time-difference in the resolution of advancement vs height. Perhaps performance differences between the two features would have been observed if truncations were made in smaller intervals, such as at R+15, R+20, R+25, and R+30.

Hearing-impaired Data

Compared to normal hearing listeners, less information is availble in the literature on the performance of hearing-impaired listeners for truncated stimuli. In this investigation, unaided hearing-impaired listeners did not demonstrate asymptotic consonant recognition performance until 10 ms after consonant release, with performance never reaching that of the normal hearing listeners. In the investigation by Dubno et al (1987), the listeners with flat and gradually falling audiometric configurations did not demonstrate asymptotic performance until aprroximately 40 ms after consonant release, yet did reach the performance levels of the normal hearing listeners (for /b/ and /d/ paired with /ɑ/). Compared to the present investigation, the need for longer stimulus segments for the listeners in the Dubno et al (1987) investigation may well be due two aspects of the stimuli used: (1)Dubno et al (1987) used synthesized speech which may contain fewer of the cues to consonant identity which occur in natural speech, and (2)Dubno et al (1987) used isolated CVs, eliminating those cues which may be present in the preceding vowel and vowel-consonant transition. The near-normal identification performance by the Dubno et al (1987) hearing-impaired subjects may be attributable to the fact that they had only to decide between three reponse alternatives (only resolve place), whereas the listeners in the present investigation had to decide from among ten

response alternatives (resolve place, manner, and voicing).

In terms of feature resolution, the results in for place (Figure 5), manner (Figure 6), and voicing (Figure 7) indicate that the group differences observed for overall consonant performance (Figure 3) were primarily due to the relatively poorer performance of the hearing-impaired subjects in resolving place information. The significant Group x Truncation interaction for the place data support the observation that the different groups can resolve place at different points in the stimulus waveform. In accordance with the observations of Dorman and Hannley (1985), hearing-impaired listeners are more likely to demonstrate errors for place identification than manner or voicing. Although the hearing-impaired listeners in this investigation did achieve near-normal place resolution for the full-duration stimuli, they did need a significantly greater proportion of the stimulus waveform in order to resolve place identity. The normal hearing listeners appear to be able to garner place information for the region of the vowel-consonant transition, whereas the hearing-impaired listeners, whether aided or unaided, need to wait until some point in the nominal production of the consonant in order to garner place information.

In terms of vowel performance, the overall results (Figure 4) are in accordance with the findings of Owens et al (1968) that vowel resolution for hearing-impaired

(except the severely and profoundly impaired) listeners tends to be similar to that of normal hearing listeners. Tongue advancement and tongue height did not appear to be differentially resolved. The superior performance of the normal listeners at R+10 was not great enough to support a significant Group or Group x Truncation effect in the ANOVA results for either tongue advancement or tongue height.

Consonant vs Vowel Performance

Except for HI4 (to be discussed below), the impaired-unaided listeners in this investigation showed near-normal performance for the full-duration vowel stimuli despite reduced performance for the full-duration consonant stimuli. Thus, the adage that listeners with mild and moderate sensorineural hearing loss do not demonstrate perceptual difficulties for vowels may need to be revised to indicate that performance for full-duration vowels is similar between the groups. The superior performance of the normal hearing listeners at R+10 suggests that unaided hearing-impaired listeners may need a greater proportion of the stimulus waveform before they can make proper vowel identifications. The suggestion is that whereas normal hearing listeners can obtain sufficient vowel information from the temporal region of the consonant-vowel transition (consistent with, for example, Jenkins et al, 1983), hearing-impaired listeners may be more dependent upon the information from the temporal region of the formant steady-

states. The difference between vowel and consonant performance for the impaired-unaided group is that, despite needing more of the waveform, the listeners could eventually reach near-normal recognition performance for the vowels. Conversely, for the consonants, the hearing-impaired listeners not only needed more of the waveform in order to reach asymptotic identification performance, this asymptote was reduced compared to that of the normal hearing listeners.

Effect of Amplification

Given that manner and voicing performance was similar for all three groups at all truncation points, the only consonant feature which had the potential to be aided by the presence of amplification was place. As was expected, the presence of amplification did allow for improved resolution of place identity. Since place information is assumed to be principally carried in the region around 2000 Hz (Pickett, 1980; Van Tasell, 1981), and given that all hearing-impaired subjects were provided with significant functional gain at 2000 Hz (see Table 2), the performace improvment with the use of amplification was likely due to the increased audibility of speech energy in the higher frequencies. More specifically, post-hoc measures of the peak energy in the octave-band centered at 2000 Hz were made for the full-duration consonant productions. Across the ten consonants, peak-energy in the 2000 Hz region ranged from 57 to 64 dB SPL. A rough translation to db HL

would place this information in the range from 52 to 59 dB HL (Cox & McCormick, 1987). Examination of the thresholds in Table 1 would suggest that this information would fall below threshold for HI2, HI3, and HI4, and would be at a low sensation level for HI1. However, with the functional gain provided to these subjects (Table 2), this speech information should have been clearly audible for all subjects.

For full-duration phoneme recognition, it appears that the use of amplification allowed the hearing-impaired listeners to approximate normal performance. However, the effect of amplification to reduce the gap between performance by normal and impaired listeners is not consistent until the later truncation times. For example, for the overall consonant performance (Figure 3), normal and impaired-aided scores are very similar up to C+10. However, at C+25 and MDPT, the normal hearing listeners were outperforming the impaired-aided listeners. It is not until R+10 that performance is similar between these two groups. This consonant effect is especially apparent when reviewing the place identification performance (Figure 5). Performance for the normal and impaired-aided groups is similar from the R-10 truncation point on, but considerable performance differences are present from C-10 through MDPT. This same sort of performance differential also was present in the vowel data, as impaired-aided performance fell short

of normal performance at the R+10 truncation point. Thus, although the use of amplification does allow for near-normal performance for the full-length stimuli used here, the impaired-aided subjects, unlike the normal hearing listeners, apparently were not able to use information from the earlier portions of the waveforms.

This aspect of the data demonstrates that recognition performance for full-duration, isolated phonemes may not be the most sensitive measure of the benefit provided by amplification. Over the recent years, there has been growing dissatisfaction with the use of traditional clinical tests of speech perception when attempting to measure the benefit of amplification (Studebaker, 1982). Perhaps, at some point in the future, measures such as those made in this investigation may prove to document more specifically the effect of the use of hearing aids.

Cue Use by the Hearing Impaired

Recall that HI4 demonstrated both generally poorer performance and unique error patterns. It seems that the hearing-impairment of HI4 has quantitatively and qualitatively different effects on phoneme perception as compared to the impairments of HI1, HI2, and HI3. The unique error patterns demonstrated by HI4 highlight a concern that is pervasive in any behavioral investigations using the sensorineural hearing impaired. These subjects often show heterogeneous rather than homogeneous patterns

of skills. Therefore, based upon the current data, any generalizations concerning speech perception skills made across hearing-impaired listeners are tenuous. Humes (1982) makes a similar observation when reviewing the performance of sensorineural hearing-impaired listeners on a variety of psychoacoustic tasks. Humes (1982) points out that wide differences in performance can occur even between subjects with rather similar audiometric thresholds. Notice that, in Table 6, although significant, the correlations between the performance of HI1, HI2, and HI3 are generally lower than those for the normal hearing listeners. Also, notice that, in the unaided condition, there was evidence of heterogeneous feature resolution abilities (see Tables 11 & 15).

Although HI4 had, in general, the poorest audiometric thresholds, the difference in sensitivity between HI4 and, for example, HI2 or HI3 would not seem to be great enough to account for the marked performance differences for the truncated speech stimuli. It is true that HI4 was provided with less than optimal amounts of functional gain at 2000 and 4000 Hz. However, decreased audibility of speech energy in the higher frequencies would be expected to have the greatest impact upon the perception of place information. Yet, review of the data in Table 18 indicates that HI4 demonstrated better resolution for place than for either manner or voicing. If manner and voicing perception

are indeed more dependent upon temporal resolving power and place more depedent upon frequency resolution, it would then appear that HI4 must suffer to a greater degree from dysfunction in the temporal domain.

An alternate interpretation for the performance of HI4, and for hearing-impaired listeners in general, is that we may not fully understand just what cues an impaired listener will use to make phonemic identifications. A variety of authors (e.g., Pickett, 1980; Van Tasell, 1981; among others) have provided descriptions of what cues are assumed to be used by normal hearing listeners while processing speech. Any aspect of the hearing impairment which would compromise the perception of those cues used by the normal listener would thus be expected to disrupt speech recognition. However, what this line of argumentation does not consider is that other, supplemental cues may be available to augment those cues eliminated by the hearing impairment. Recall that Revoile and her colleagues (Revoile et al, 1982, 1985, 1987) have demonstrated that hearing-impaired listeners tend to be more dependent upon temporally based phonemic cues whereas normal hearing subjects tend to be more dependent upon spectrally based cues. Thus, loss of one source of phonemic information does not necessarily mean that other sources of information can not be used as supplement.

Review of the hearing-impaired group data on place

identification (Figure 5) provides a good example of the use of supplemental phonemic information. Collins (1984) argued that the study of hearing-impaired listeners' discrimination abilities for tone glides in the vicinity of 2000 Hz may help us to better understand their speech perception difficulties, since consonantal place is typically marked by the direction and rate of F2 transitions. However, a variety of investigators (Dreschler & Plomp, 1985; Lutman & Clark, 1986; Ochs, 1987; Thibodeau & Van Tasell, 1987) have found limited correlation between frequency resolution in the vicinity of F2 and speech recognition performance. As can be seen in Figure 5, the normal hearing listeners in this investigation apparently could garner place information from the temporal portion of the waveform which would include the vowel-consonant transition. The unaided hearing-impaired listeners could not use this early occurring information, yet could still achieve near-normal place resolution for the full duration stimuli. These hearing-impaired liteners must have garnered their place information from some other portion of the stimulus waveforms. In a related manner, Lacroix and Harris (1979) compared speech recognition performance for a group of high-frequency hearing-impaired listeners to that of a group of normal hearing subjects whose thresholds were masked to match those of the hearing-impaired subjects. The investigators observed that the hearing-impaired

subjects outperformed the masked normal subjects. Lacroix and Harris (1979) interpreted the results to indicate that the hearing-impaired subjects had learned to make use of supplemental phonemic information which is not typically used by normal hearing listeners. It would seem that any investigation into cue use by the hearing impaired must be careful not to make overly restrictive assumptions as to what phonemic information can and is used by listeners.

Error Responses

Review of the selection probabilities (Tables 8 & 10) and the error-type analyses (Tables 12, 13, 14, 16, & 17) suggests that the errors made by the subjects were more likely due to the stimulus manipulation procedure used in this investigation than due to any basic perceptual differences between normal and hearing-impaired listeners. Recall that, during consonant testing, the subjects in all groups demonstrated a tendency at the early truncation times to select voiceless stops, especially /p/. During vowel testing, the tendency for all groups was to select /u/. These response biases are further reflected in the specific types of errors made, as consonant errors for all three groups reflected the tendency to substitute phonemes which were labial, stopped, and/or voiceless. During vowel testing, all groups demonstrated a tendency to substitute high for low and mid vowels, and two of the groups demonstrated the tendency to substitute back for front vowels. The only significant group by error-type

interaction (suggesting that the groups differed as to the types of errors made) was for vowel tongue advancement. Thus, although the groups differed as to the resolution of consonant place, in general, all three groups demonstrated similar behavior in terms of the errors made.

The tendency to select voiceless plosives as error responses at the early consonant truncation times may likely reflect the fact that these stimuli were terminated before many of the major cues for frication (aperiodic noise during closure), nasality (poles and zeroes during closure), and voicing (low-frequency periodic energy) had occurred. The closure portion of a voiceless stop is marked essentially by a rapid cessation of energy, with silence until the release. If truncation occurs for voiced stops, fricatives, and nasals before major manner and voicing cues can occur, the resultant stimuli will demonstrate a rapid cessation of energy, followed by silence. Thus, the truncation procedure may be expected to induce the perception of a voiceless stop.

The tendency to substitute labials for alveolars may be explained in the following manner. The vowel before the truncated was /ɑ/, which is characterized by a relatively low-frequency F2 (Pickett, 1980). The locus for F2 in labials is also in the similar low-frequency range, with alveolars demonstrating an F2 locus in the higher

frequencies (Pickett, 1980). If truncation for alveolar consonants occurs before F2 can rise, the induced perception may be one of no or little change in the location of F2, suggesting a labial place of articulation.

A similar line of reasoning may explain the tendency to select the high back vowel /u/. The consonant preceding the test vowel was /b/ (characterized by a low-frequency release burst). The vowel /u/ also demonstrates the lowest F2 of any of the vowels used in this investigation (Pickett, 1980). If truncation occurs before F2 can move upward in frequency, the induced perception may be one of a /b/ followed by /u/. It is unclear, however, why the aided hearing-impaired listeners demonstrated a tendency to substitute front for back vowels.

Despite the interaction of error-type by group for tongue advancement, it is interesting that all groups were making similar sorts of substituions when the test phoneme could not be fully resolved. Both the normal and impaired listeners appeared to be using similar strategies when attempting to determine phoneme identity.

The Perception of Ongoing Speech

In this investigation, isolated one- and two-sylable productions were used. However, it can be argued that these results do have implications for the perception of natural, ongoing speech. There is some evidence from

investigations into the acoustic characteristics of ongoing speech which may have implications for the perception of this ongoing signal by hearing-impaired listeners. Miller (1981) reported that listeners cannot be dependent on steady-state formant frequencies in order to identify vowels since, when speech is naturally speeded-up, vowels often do not demonstrate formant steady-states. In fact, the formant transitions often do not even reach target frequencies. Therefore, under certain conditions, the listener must be able to make phonemic identifications based upon those formant transitions. However, review of the data from Figure 4 indicates that the hearing-impaired subjects did not reach asymptotic performance until 100 ms after the release of the consonant, a point after which the formants of the vowel stimuli used in this investigation have reached steady-state (see Appendix A). Similarly, Picheny et al (1986) reported that both consonants and vowels in conversational speech are shorter and are less likely to reach acoustic targets. Again, listeners may not be afforded the luxury of waiting for more of the stimulus waveform to occur before reaching a phonemic decision. The stimuli used in this investigation were produced in a deliberate and well-formed manner. The speaker made a conscious effort to reach articulatory targets when producing the test consonants and vowels. In full-duration form, these stimuli were, in most cases, highly intelligible for the hearing-impaired listeners. Yet, when

these same stimuli were truncated (in certain respects similar to conversational-style productions), the hearing-impaired listeners were less successful in resolving identity. Natural, ongoing speech will more often include briefer, reduced phonemic productions. The effect of hearing-impairment may not fully be reflected in the identification of isolated, well-formed phonemes. Rather, hearing-impaired listeners may not be able to extract enough useful information from rapid, ongoing acoustic events.

The results of the present study can also be viewed in terms of model of perceptual processes in general. Anderson (1985) and Martindale (1981) review a variety of models of attention during perception and information processing. These models typically view attention as a limited commodity. In other words, at any given point in time, an observer (listener) can only put forth a limited amount of mental effort. The more difficult the perceptual task, the less capacity is left over for other cognitive processes, such as interpreting input stimuli, relating to stored information, or committing the input stimuli to memory. Downs and Crum (1978) provide a specific example of limited processing capacity in the realm of speech perception. Downs and Crum (1978) presented their subjects with associated pairs of words and, later, required the subjects to recall one member of the pair when presented with the other member of the pair. The paired words were

presented in various levels of background competing speech. During presentation of the word pairs, the subjects were also instructed to press a button any time that they noticed a signal light come on. The subjects were further instructed to provide primary attention to learning the word pairs and were to monitor the signal light using only whatever leftover capacity was available. The results indicated that the listeners recalled the pair members equally well regardless of the signal-to-competition ratio during the learning phase. However, the subjects took longer to respond to the signal light in the more difficult signal-to-competition conditions. The results are interpreted as suggesting that the more difficult the listening task, the less capacity remains to perform other cognitive tasks. As far as the results from this investigation are concerned, this model of attention would predict that as the amount of the stimulus waveform that must be processed before an identification can be made increases, less capacity is left over to perform other cognitive processes on that information.

Neisser (1976) models visual perception as a constructive process. He argues for the existence of a perceptual cycle, consisting of three components: the schema, the exploration, and the object. The perceiver's stored schema directs the exploration of the environment. During exploration, the perceiver samples information

available in the object. The information available from the object is then used to modify the stored schema. In other words, Neisser (1976) views perception as an interaction of stored information ("top-down" effects) and incoming stimulus information ("bottom-up" effects). Any factor which limits the amount of information that can be garnered from the incoming stimulus will be expected to disrupt this natural interaction between incoming and stored information. In the present study, hearing impairment and truncation can be viewed as factors limiting information.

Specifically in terms of models of speech perception, Marslen-Wilson and Tyler (1973) and Marslen-Wilson and Welsh (1978) and then later Elman and McClelland (1984) and Elman and McClelland (1986) have viewed speech perception as an interactive parallel process. In other words, the perceiver uses a variety of sources of information in parallel to arrive at word recognition. These sources of information include both the acoustic input and stored linguistic information such as word frequency, syntatic, and semantic knowledge. More specifically, Marslen-Wilson and Welsh (1978) argue that the listener starts with the raw acoustic input. Once enough of this data can be interpreted in order to make a phonemic identification, top-down processes are called upon to limit the possible interpretations of the following input stimuli. The implicit assumption of this model is that the relative

benefit of bottom-up versus top-down influences favors top-down information. In other words, it is much easier to interpret incoming acoustic information if the listener can limit the number of possible interpretations. To extend this logic one more step, the sooner a phoneme can be identified, the easier the perceptual process. Thus, given the fact that hearing-impaired subjects required greater proportions of the stimuli before correct identifications could be made, it would be expected that the overall perceptual task may be more difficult.

Follow-up Investigations

The results of this investigation should be viewed as only a preliminary description of the time course of acoustic/phonemic cue integration in hearing-impaired listeners. There are at least four different additional questions that deserve attention:

(1)The relevance of these results to the perception of ongoing speech was established only through the logical extension of the points made in previous data-based and theoretical papers. Direct tests need to be made to establish whether listeners who show delays in phonemic identifications do in fact have greater overall difficulties in processing ongoing speech.

(2)The data reported in this paper were based only

upon the performance of four hearing-impaired listeners. Clearly, a larger subject pool would help to establish more firmly the nature of performance differences between normal and hearing-impaired listeners. More specifically, information is needed on performance differences between hearing-impaired subjects with a variety of audiometric configurations and between those subjects who demonstrate overall better or poorer word recognition abilities.

(3)Elderly subjects often demonstrate processing difficulties which appear to be independent of peripheral hearing loss. Thus, this group may provide interesting information on how incoming information is processed by a dysfunctioning central system.

(4)Finally, hearing-impaired listeners often report marked difficulties in perceiving speech in noise and reverberation. Amplification appears to be of limited benefit in these situations. Therefore, it would be instructive to establish if amplification can continue to allow for identifications based upon less of the acoustic waveform under conditions of noise and reverberation.

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TABLE 1

Audiometric data for the hearing-impaired subjects.

				Thresholds (db HL)					
Subject	Ear	Age	Sex	.25 kHz	.5 kHz	1 kHz	2 kHz	4 kHz	8 kHz
HI1	R	21	F	20	25	40	50	45	65
	L			30	30	40	60	55	75
HI2	R	20	F	15	5	80	80	65	50
	L			20	45	80	80	65	65
HI3	R	20	F	35	50	65	75	65	60
	L			50	65	75	65	60	55
HI4	R	35	M	60	55	65	60	85	90+
	L			60	55	75	80	95	90+

TABLE 2

Spectral enhancement (HI1) and binaural functional gain (HI2, HI3, HI4) for the hearing-impaired subjects.

	Frequency				
Subject	.25 kHz	.5 kHz	1 kHz	2 kHz	4 kHz
HI1	10	10	20	23	23
HI2	5	25	40	40	20
HI3	15	30	35	40	20
HI4	15	20	30	25	15

TABLE 3

Word recognition scores (CID W-22s) for the hearing-impaired subjects.

Subject	W-22 Percent Correct	
	Unaided	Aided
HI1	18%	80%
HI2	26%	56%
HI3	32%	92%
HI4	0%	0% 20% (@60dB HL)

TABLE 4

Contrasts represented by the ten test consonants.

Place	Manner					
	Stop		Fricative		Nasal	
	Voiced	Unvoiced	Voiced	Unvoiced	Voiced	Unvoiced
Labial	b	p	v	f	m	-
Alveolar	d	t	z	s	n	-

TABLE 5

Contrasts represented by the six test vowels.

Tongue Height	Tongue Advancement	
	Front	Back
High	i	u
Mid	e	o
Low	ɑ	ae

TABLE 6

Pairwise correlation coefficients between subject scores. Asterisks indicate correlations that are significant (p<.0001).

Consonants

Normal

	N2	N3
N1	.84*	.78*
N2		.83*

Impaired-Unaided

	HI2	HI3
HI1	.46*	.44*
HI2		.58*

Impaired-Aided

	HI2	HI3	HI4
HI1	.67*	.66*	.07
HI2		.78*	.06
HI3			.35

Vowels

Normal

	N2	N3
N1	.93*	.97*
N2		.90*

Impaired-Unaided

	HI2	HI3	HI4
HI1	.83*	.66*	.63*
HI2		.67*	.63*
HI3			.59

Impaired-Aided

	HI2	HI3	HI4
HI1	.79*	.83*	.79*
HI2		.82*	.68*
HI3			.81*

TABLE 7

Percent correct identification for the consonant stimuli for each phoneme and truncation point averaged across subjects within groups.

		Truncation Point								
		C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
b	NRL	6.7	3.3	70	83.3	100	86.7	100	96.7	96.7
	HI-U	0	0	46.7	86.7	90	100	96.7	93.3	100
	HI-A	6.7	6.7	66.7	100	90	93.3	100	100	96.7
p	NRL	20	10	76.7	73.3	96.7	100	90	100	100
	HI-U	56.7	56.7	43.3	50	46.7	56.7	56.7	26.7	36.7
	HI-A	60	36.7	70	66.7	66.7	56.7	73.3	30	33.3
d	NRL	10	3.3	70	93.3	100	100	100	100	100
	HI-U	3.3	6.7	66.7	83.3	73.3	86.7	66.7	83.3	80
	HI-A	3.3	26.7	80	83.3	93.3	96.7	100	100	100
t	NRL	10	93.3	100	93.3	80	66.7	96.7	96.7	96.7
	HI-U	13.3	26.7	16.7	26.7	13.3	33.3	56.7	53.3	56.7
	HI-A	10	70	93.3	73.3	73.3	80	93.3	93.3	100
v	NRL	20	26.7	90	100	90	100	100	100	100
	HI-U	0	3.3	30	66.7	60	50	80	83.3	90
	HI-A	0	20	80	90	86.7	90	96.7	93.3	96.7
f	NRL	13.3	40	46.7	83.3	90	100	100	100	100
	HI-U	23.3	43.3	43.3	53.3	53.3	63.3	80	93.3	83.3
	HI-A	40	26.7	66.7	63.3	66.7	70	86.7	90	90
z	NRL	3.3	63.3	100	93.3	100	100	93.3	96.7	100
	HI-U	6.7	46.7	46.7	46.7	46.7	70	86.7	73.3	80
	HI-A	0	40	36.7	43.3	46.7	83.3	86.7	90	96.7
s	NRL	3.3	40	23.3	50	93.3	96.7	100	96.7	100
	HI-U	3.3	13.3	13.3	36.7	50	63.3	56.7	50	70
	HI-A	6.7	10	6.7	10	86.7	96.7	100	96.7	100
m	NRL	53.3	43.3	40	100	100	100	96.7	100	100
	HI-U	3.3	6.7	13.3	56.7	90	100	96.7	93.3	93.3
	HI-A	30	40	43.3	86.7	100	96.7	100	100	93.3
n	NRL	10	0	10	93.3	100	96.7	100	96.7	100
	HI-U	10	6.7	60	86.7	63.3	96.7	100	96.7	96.7
	HI-A	13.3	20	80	96.7	83.3	96.7	100	100	100

TABLE 8

Selection probabilities for each consonant response alternative averaged over the first four truncation times and over the ten test consonants. A single asterisk marks any individual mean which was significantly ($p<.05$) greater than the unbiased, expected selection rate of .1. A double asterisk marks any group mean significantly greater than .1.

Response Alternative

	b	p	d	t	v	f	z	s	m	n
N1	.04	.208	.055	.21*	.13	.133	.08	.045	.043	.055
N2	.08	.073	.113	.193	.163	.148	.078	.033	.085	.038
N3	.053	.243*	.143	.173	.075	.028	.06	.048	.123	.045
Mean	.058	.174**	.103	.192**	.123	.103	.073	.042	.08	.046
HI1-U	.03	.333*	.02	.083	.145	.318*	.01	.01	.018	.038
HI2-U	.04	.213*	.103	.253*	.073	.018	.03	.078	.093	.1
HI3-U	.05	.18	.148	.145	.07	.125	.13	.05	.023	.063
Mean	.04	.242**	.09	.16**	.096	.153	.057	.046	.044	.067
HI1-A	.058	.256*	.063	.11	.15	.228*	0	0	.085	.053
HI2-A	.103	.163	.143	.125	.12	.093	.033	.025	.075	.108
HI3-A	.073	.21*	.128	.165	.098	.103	.1	.028	.038	.06
Mean	.078	.209**	.111	.133	.123	.141	.044	.018	.066	.073
HI4-A	.04	.193	.043	.20	.04	.085	.103	.088	.078	.083

TABLE 9

Percent correct identification for the vowel stimuli for each phoneme and truncation point averaged across subjects within groups.

Phoneme	Group	Truncation Point					
		R-25	R-10	R+10	R+25	R+100	Full
i	NRL	3.3	3.3	96.7	100	100	96.7
	HI-U	20	16.7	20	70	100	100
	HI-A	16.7	10	60	100	100	100
e	NRL	3.3	0	0	76.7	63.3	96.7
	HI-U	23.3	10	13.3	46.7	70	100
	HI-A	3.3	10	33.3	100	93.3	100
ɑ	NRL	3.3	13.3	86.7	100	100	93.3
	HI-U	6.7	16.7	36.7	90	76.7	73.3
	HI-A	10	36.7	93.3	60	100	100
u	NRL	60	73.3	100	86.7	100	100
	HI-U	23.3	43.3	76.7	83.3	100	96.7
	HI-A	46.7	43.3	93.3	100	100	100
o	NRL	33.3	6.7	80	66.7	93.3	96.7
	HI-U	33.3	6.7	40	63.3	90	96.7
	HI-A	20	6.7	30	60	83.3	100
ae	NRL	10	3.3	73.3	100	100	100
	HI-U	3.3	3.3	13.3	56.7	66.7	60
	HI-A	0	6.7	10	90	100	100

TABLE 10

Selection probabilities for each vowel response alternative averaged over the first three truncation times and over the six test vowels. A single asterisk marks any individual mean which was significantly ($p<.05$) greater than the unbiased, expected selection rate of .167. A double asterisk marks any group mean significantly greater than .167.

	Response Alternative					
	i	e	ɑ	u	o	ae
N1	.083	.094	.144	.317*	.200	.156
N2	.172	0	.078	.539*	.094	.100
N3	.056	.039	.167	.483*	.100	.156
Mean	.104	.044	.129	.446**	.132	.137
HI1-U	.189	.100	.072	.356*	.211	.072
HI2-U	.089	.078	.272	.322*	.167	.072
HI3-U	.217	.244	.094	.183	.094	.167
Mean	.165	.141	.146	.287**	.157	.104
HI1-A	.256	.239	.061	.283	.122	.039
HI2-A	.072	.067	.399*	.389*	.089	.044
HI3-A	.244	.133	.178	.194	.056	.194
Mean	.191	.146	.193	.289**	.089	.093
HI4-U	.122	.217	.183	.178	.122	.172
HI4-A	.083	.206	.172	.222	.094	.222

Table 11

Correlation coefficients for performance on consonant feature resolution between subjects within groups. Asterisks indicate significant ($p<.0001$) correlations.

	Pairwise Comparison	Place	Feature Manner	Voicing
Normal listeners				
	N1/N2	.74*	.83*	.61*
	N1/N3	.82*	.50*	.59*
	N2/N3	.76*	.44*	.64*
Impaired-Unaided				
	HI1/HI2	.20	.42*	.62*
	HI1/HI3	.08	.51*	.66*
	HI2/HI3	.34	.60*	.64*
Impaired-Aided				
	HI1/HI2	.73*	.78*	.50*
	HI1/HI3	.55*	.55*	.74*
	HI2/HI3	.69*	.71*	.52*
	HI1/HI4	.08	.24	.47*
	HI2/HI4	.11	.35	.27
	HI3/HI4	.27	.26	.30

TABLE 12

Occurrence percentages for each type of place error averaged over the first four truncation times.

	Error Type	
	Labial for Alveolar	Alveolar for Labial
N1	14	6
N2	19	9
N3	20	11
Mean	17	9
HI1-U	72	4
HI2-U	39	52
HI3-U	31	42
Mean	47	32
HI1-A	55	2
HI2-A	37	25
HI3-A	28	24
Mean	40	17
HI4-A	32	19

TABLE 13

Occurrence percentages for each type of manner error averaged over the first four truncation times.

	Error Type					
	Stop for Fricative	Fricative for Stop	Stop for Nasal	Nasal for Stop	Fricative for Nasal	Nasal for Fricative
N1	35	23	41	1	11	0
N2	29	26	31	9	26	10
N3	45	3	23	3	3	16
Mean	36	17	32	4	13	9
HI1-U	19	23	41	0	31	0
HI2-U	36	3	50	15	0	25
HI3-U	40	27	33	4	24	4
Mean	32	18	41	6	18	10
HI1-A	18	7	28	1	6	1
HI2-A	30	8	35	10	1	18
HI3-A	44	20	40	1	15	3
Mean	31	12	34	4	8	7
HI4-A	35	31	49	14	29	45

TABLE 14

Occurrence percentages for each type of voicing error averaged over the first four truncation times.

	Error Type	
	Voiced for Voiceless	Voiceless for Voiced
N1	14	43
N2	23	24
N3	14	20
Mean	17	29
HI1-U	1	57
HI2-U	15	37
HI3-U	20	33
Mean	12	42
HI1-A	2	43
HI2-A	36	26
HI3-A	19	29
Mean	19	33
HI4-A	14	54

TABLE 15

Correlation coefficients for performance on vowel feature resolution between subjects within groups. Asterisks indicate significant (p<.0001) correlations.

	Pairwise Comparison	Feature Advancement	Feature Height
Normal Listeners			
	N1/N2	.74*	.83*
	N1/N3	.80*	.87*
	N2/N3	.85*	.89*
Impaired-Unaided			
	HI1/HI2	.45	.69*
	HI1/HI3	.36	.75*
	HI2/HI3	.46	.73*
	HI1/HI4	.26	.66*
	HI2/HI4	.37	.60*
	HI3/HI4	.17	.78*
Impaired-Aided			
	HI1/HI2	.74*	.60*
	HI1/HI3	.77*	.72*
	HI2/HI3	.75*	.78*
	HI1/HI4	.51	.67*
	HI2/HI4	.50	.60*
	HI3/HI4	.51	.67*

TABLE 16

Occurrence percentages for each type of tongue advancement errors averaged over the first four truncation times.

	Error Type	
	Front for Back	Back for Front
N1	24	59
N2	12	61
N3	13	61
Mean	17	60
HI1-U	26	53
HI2-U	36	44
HI3-U	52	41
Mean	38	46
HI1-A	46	34
HI2-A	39	43
HI3-A	53	41
Mean	46	40
HI4-U	50	44
HI4-A	48	51

TABLE 17

Occurrence percentages for each type of tongue height error averaged over the first four truncation times.

	Error Type					
	Mid for Low	Low for Mid	High for Low	Low for High	High for Mid	Mid for High
N1	37	40	23	12	32	23
N2	3	18	93	2	62	7
N3	13	42	42	10	35	5
Mean	18	33	53	8	43	12
HI1-U	35	17	48	10	45	20
HI2-U	28	23	23	32	43	15
HI3-U	37	27	42	25	35	27
Mean	33	22	38	22	41	21
HI1-A	33	7	43	8	42	15
HI2-A	22	33	15	18	50	8
HI3-A	20	47	45	30	40	23
Mean						
HI4-U	40	40	32	38	35	37
HI4-A	27	48	35	32	23	35

TABLE 18

Consonant percent correct results for HI4-Aided.

	C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
Overall	11	23	28	27	26	23	30	33	32
Place	45	67	73	77	69	69	69	71	64
Manner	36	54	48	46	53	51	53	67	56
Voicing	33	53	60	68	63	50	70	62	70

TABLE 19

Vowel percent correct results for HI4-Unaided and HI4-Aided

Unaided

	R-25	R-10	R+10	R+25	R+100	FULL
Overall	10.00	13.33	18.33	30.00	65.00	81.67
Tongue Advancement	56.67	51.67	50.0	66.67	75.00	83.33
Tongue Height	21.67	28.33	28.3	48.3	85.00	98.33

Aided

	R-25	R-10	R+10	R+25	R+100	FULL
Overall	11.67	11.67	21.67	81.67	81.67	98.33
Tongue Advancement	43.33	45.00	56.67	86.67	81.67	98.33
Tongue Height	35.00	31.67	55.00	85.00	88.33	100

FIGURE 1

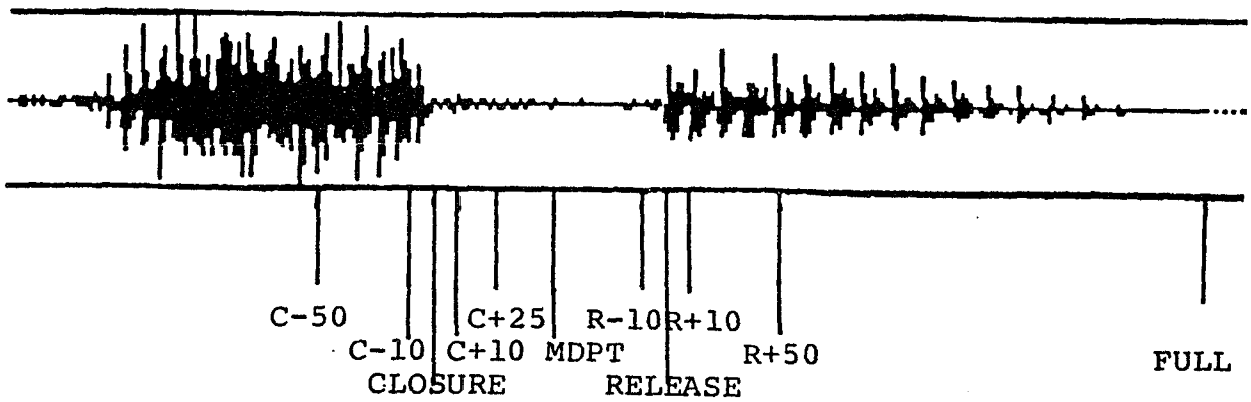

Figure 1: The waveform of the full-duration /hɑbɑ/ test stimulus. The markers indicate the consonant closure point, the consonant release point, and the various truncation points.

FIGURE 2

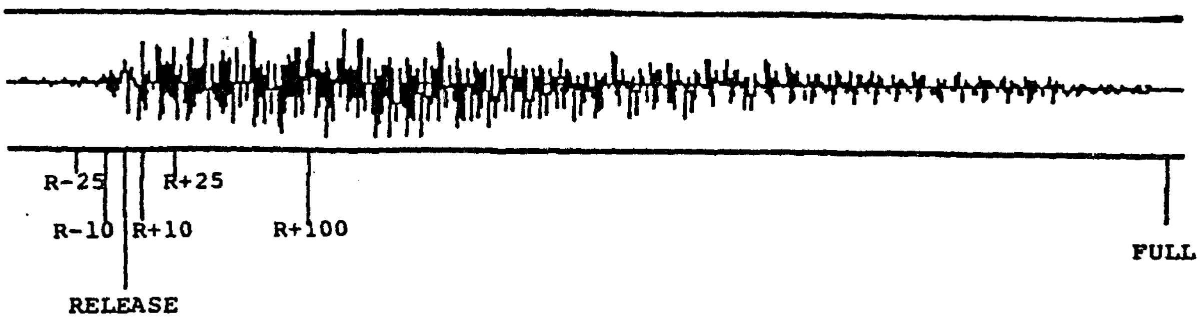

Figure 2: The waveform of the full-duration /bid/ test stimulus. The markers indicate the release point of the /b/ and the various truncation points.

FIGURE 3

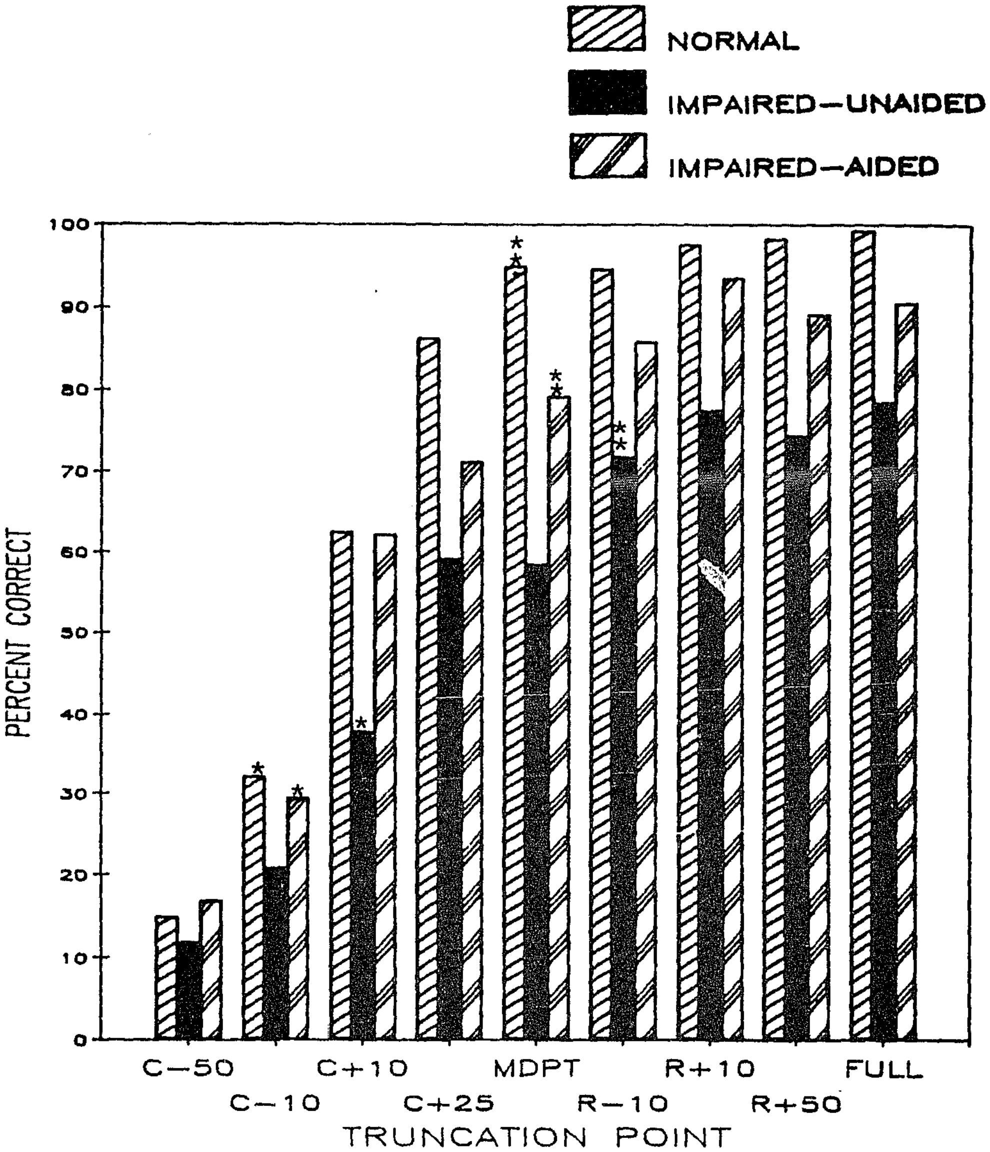

Figure 3: The percent correct averaged across the ten consonants at each truncation point. The parameter is group membership. A single asterisk indicate the earliest truncation point at which performance was significantly different from chance (p<.05). Double asterisk indicate the earliest truncation point at which performance was not significantly different from performance for the full-duration stimuli.

FIGURE 4

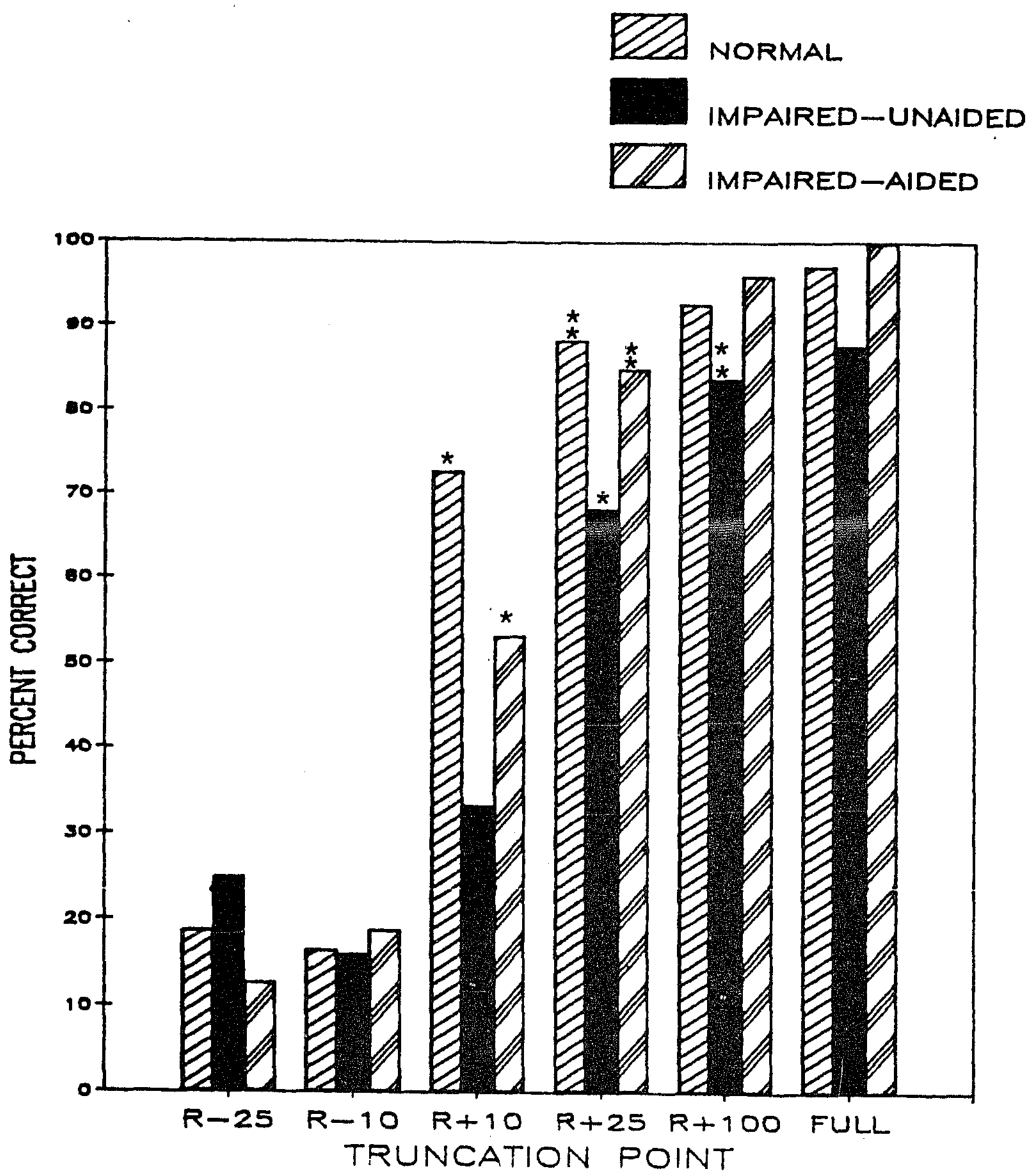

Figure 4: The percent correct averaged across the six vowels at each truncation point. The parameter is group membership. A single asterisk indicate the earliest truncation point at which performance was significantly different from chance (p<.05). Double asterisk indicate the earliest truncation point at which performance was not significantly different from performance for the full-duration stimuli.

FIGURE 5

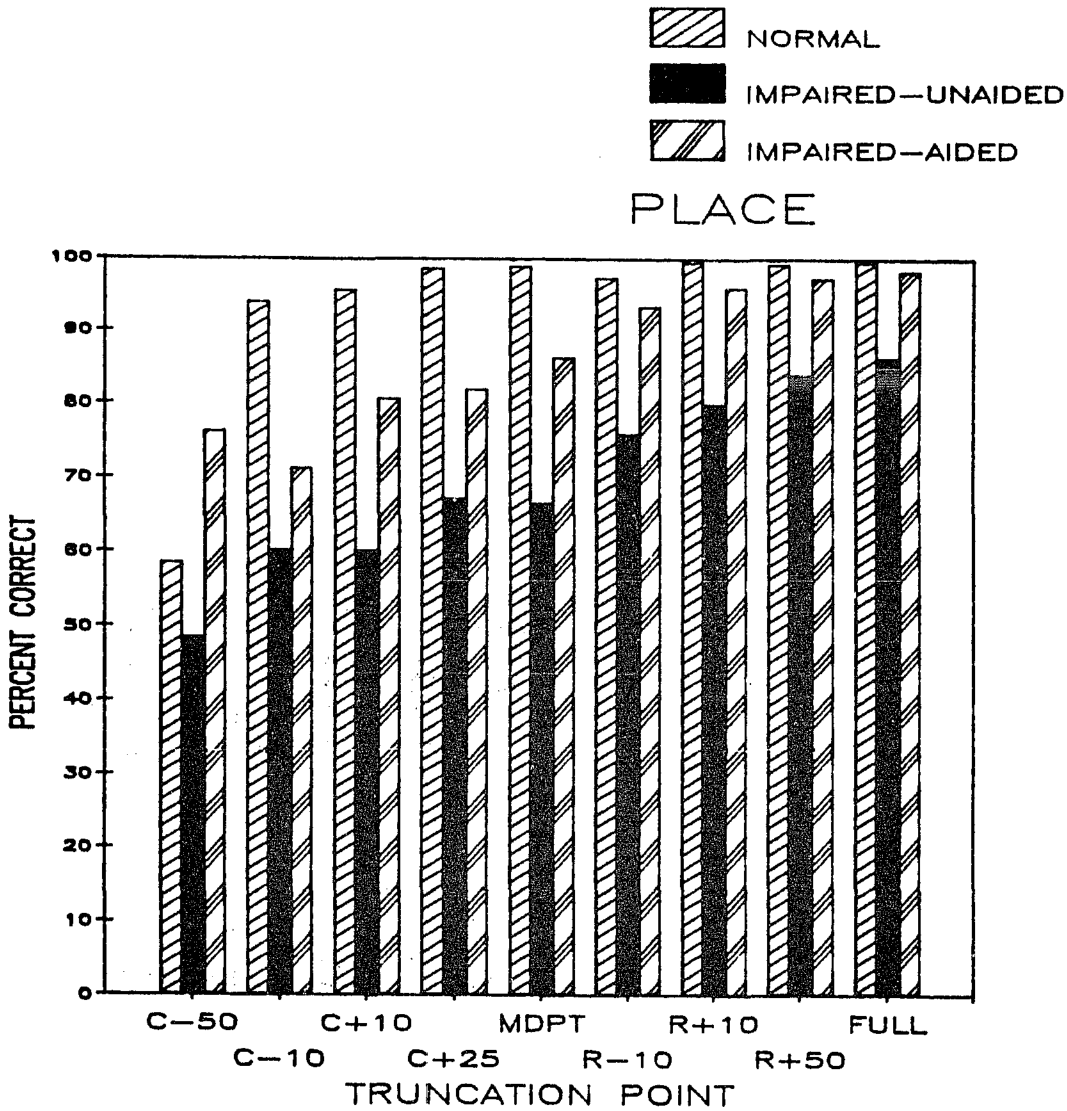

Figure 5: The percent correct Place identification averaged across the ten consonants at each truncation point. The parameter is group membership.

FIGURE 6

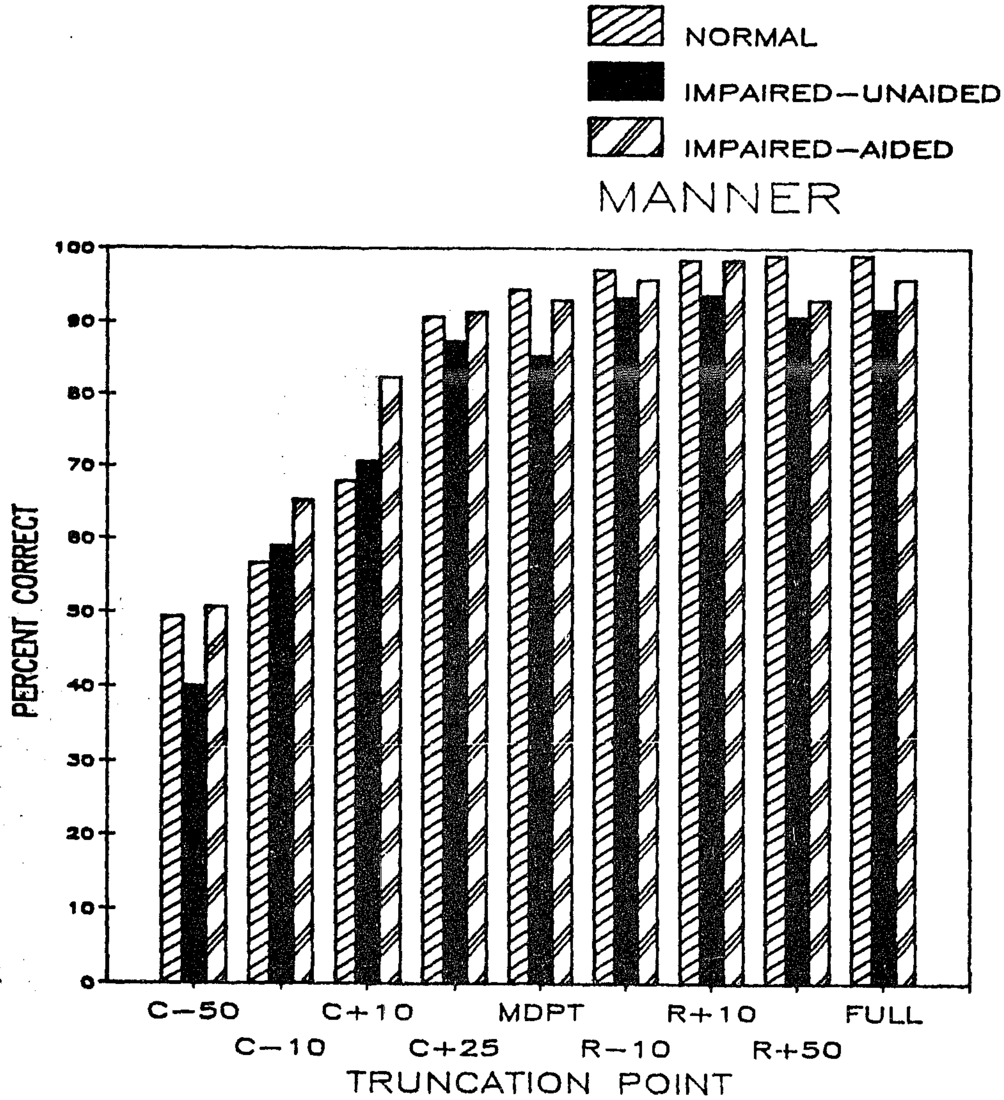

Figure 6: The percent correct Manner identification averaged across the six consonants at each truncation point. The parameter is group membership.

FIGURE 7

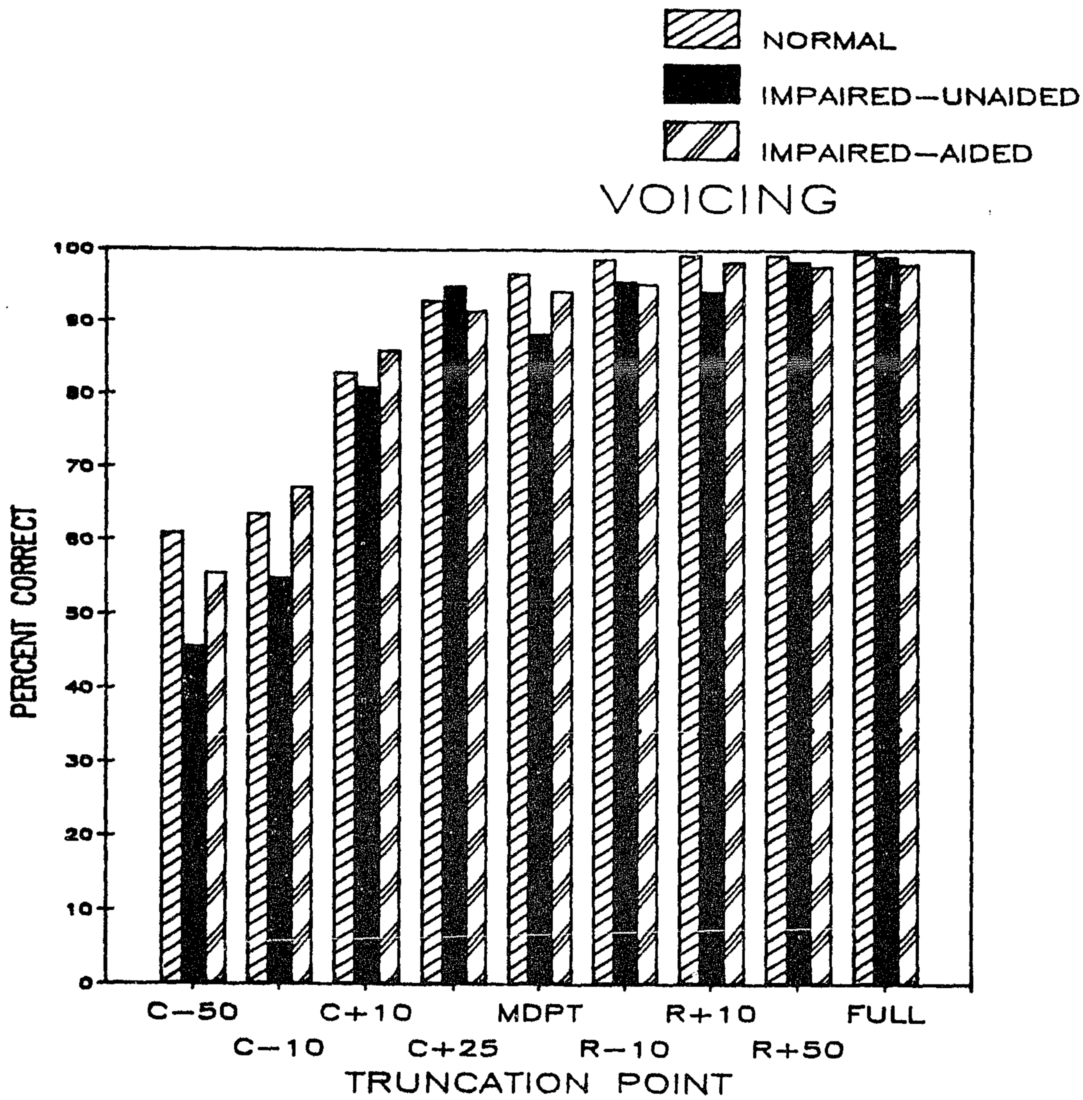

Figure 7: The percent correct Voicing identification averaged across the ten consonants at each truncation point. The parameter is group membership.

FIGURE 8

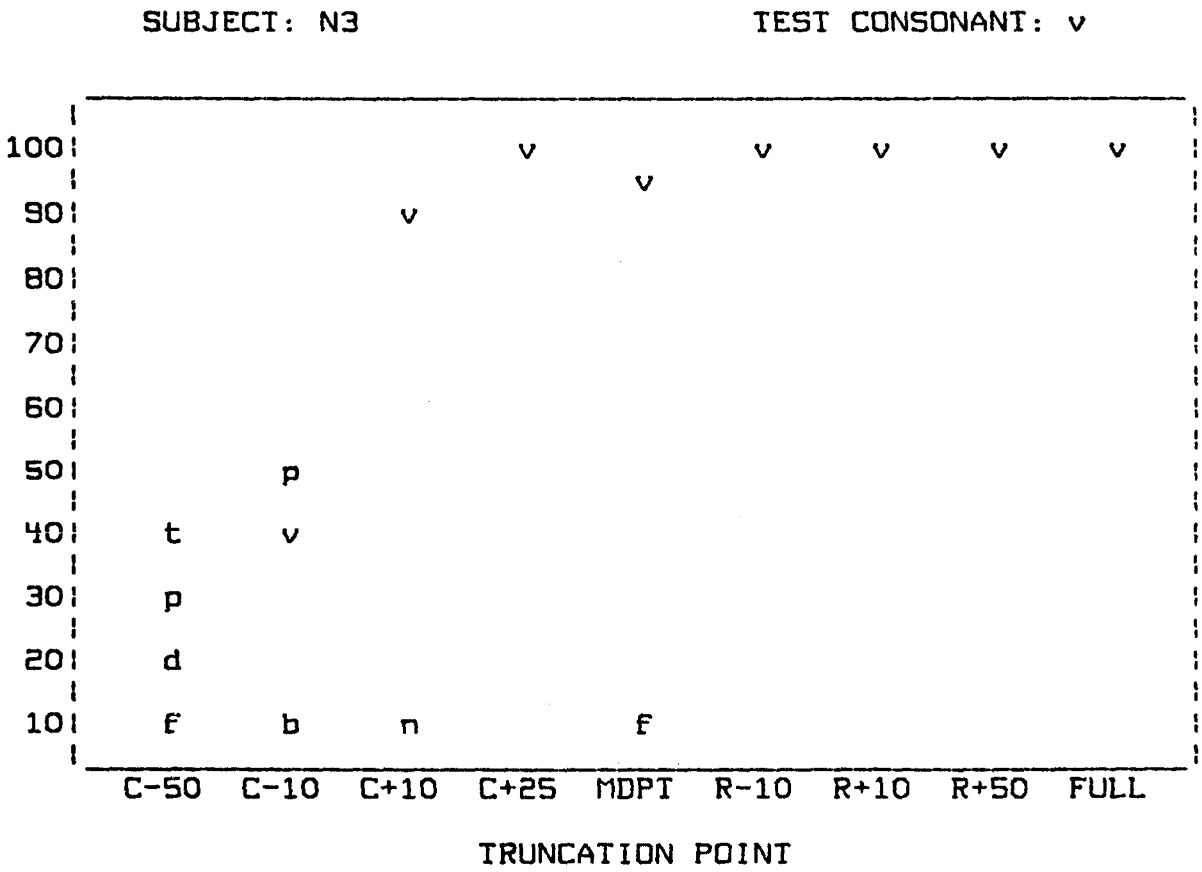

Figure 8: Response percentages to the /v/ stimulus at each truncation point for N3.

FIGURE 9

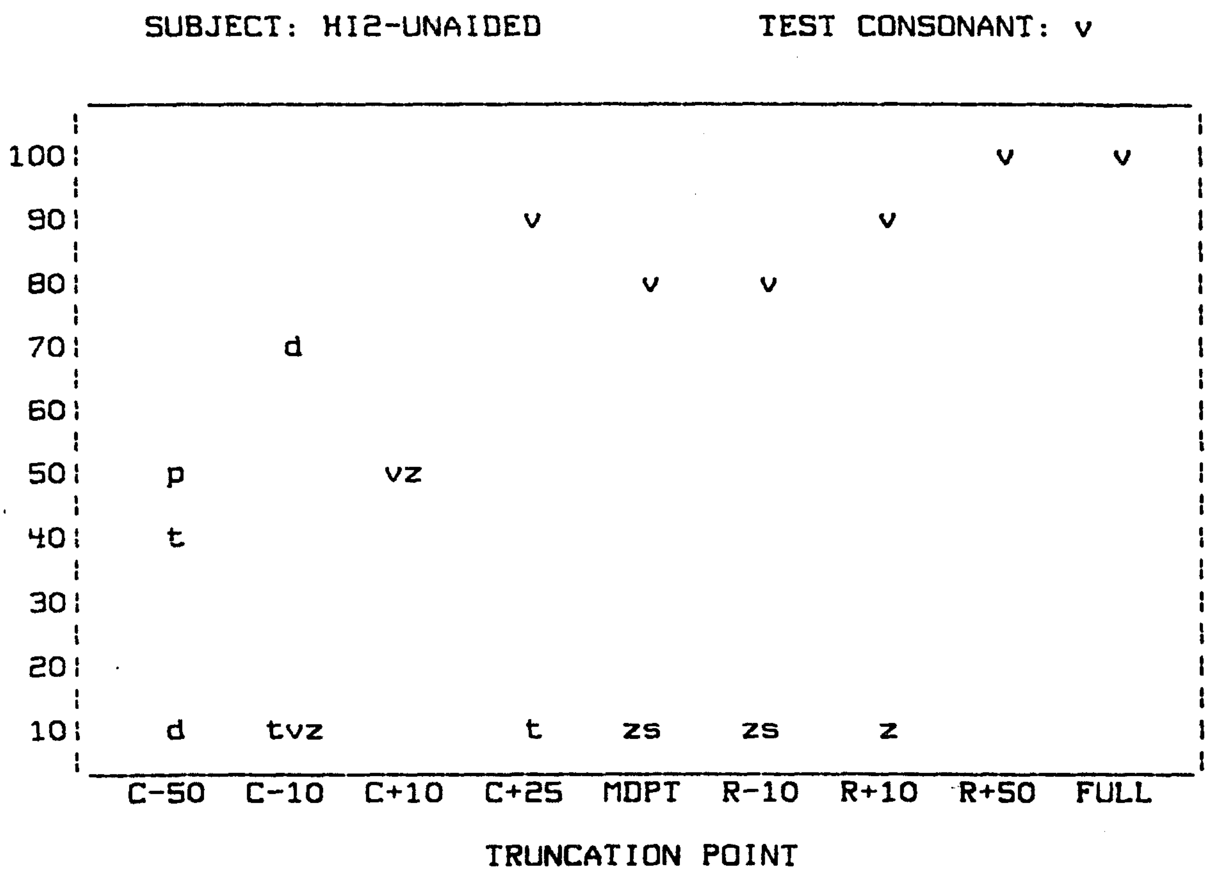

Figure 9: Response percentages to the /v/ stimulus at each truncation point for HI2-Unaided.

FIGURE 10

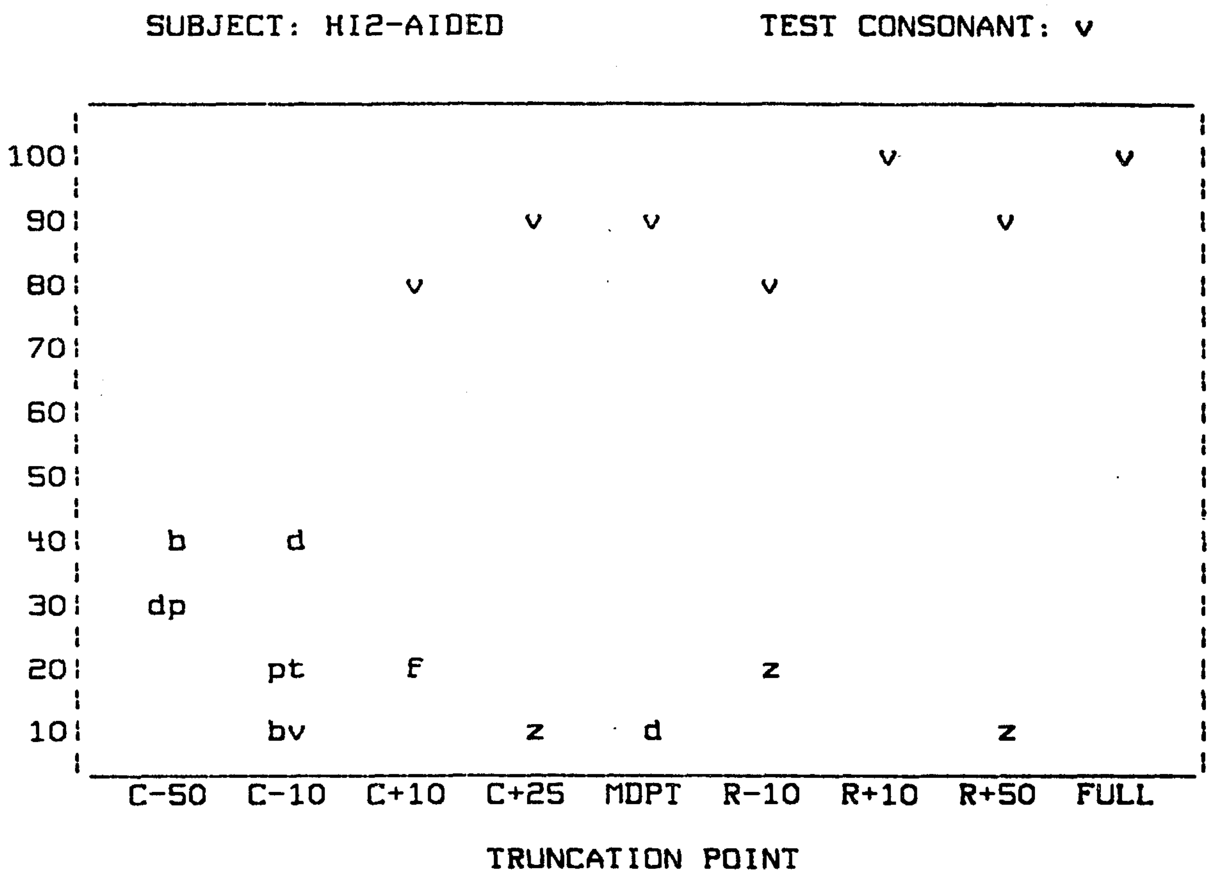

Figure 10: Response percentages to the /v/ stimulus at each truncation ponit for HI2-Aided.

FIGURE 11

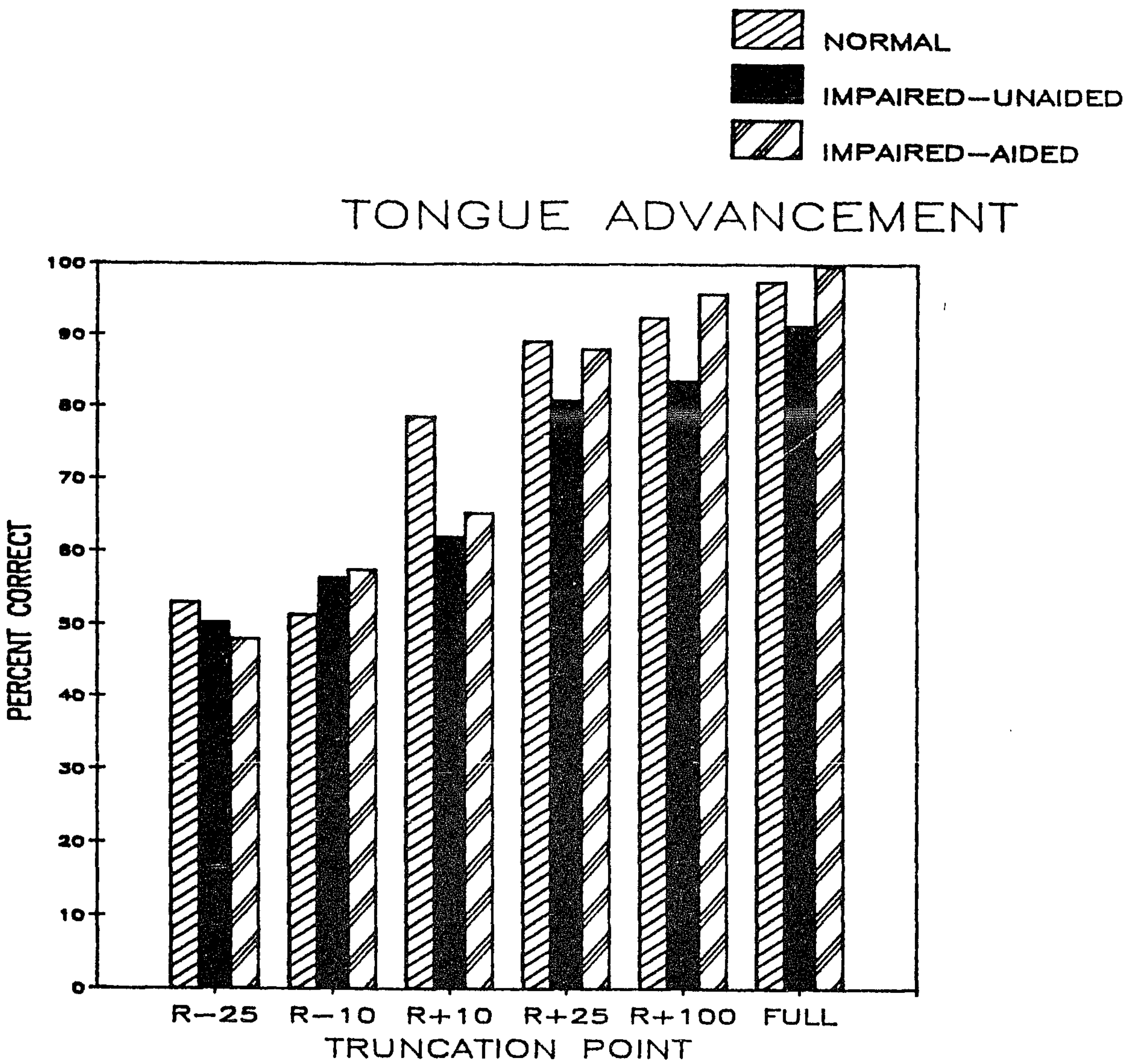

Figure 11: Percent correct Tongue Advancement identification avergaed across the six vowels at each truncation point. The parameter is group membership.

FIGURE 12

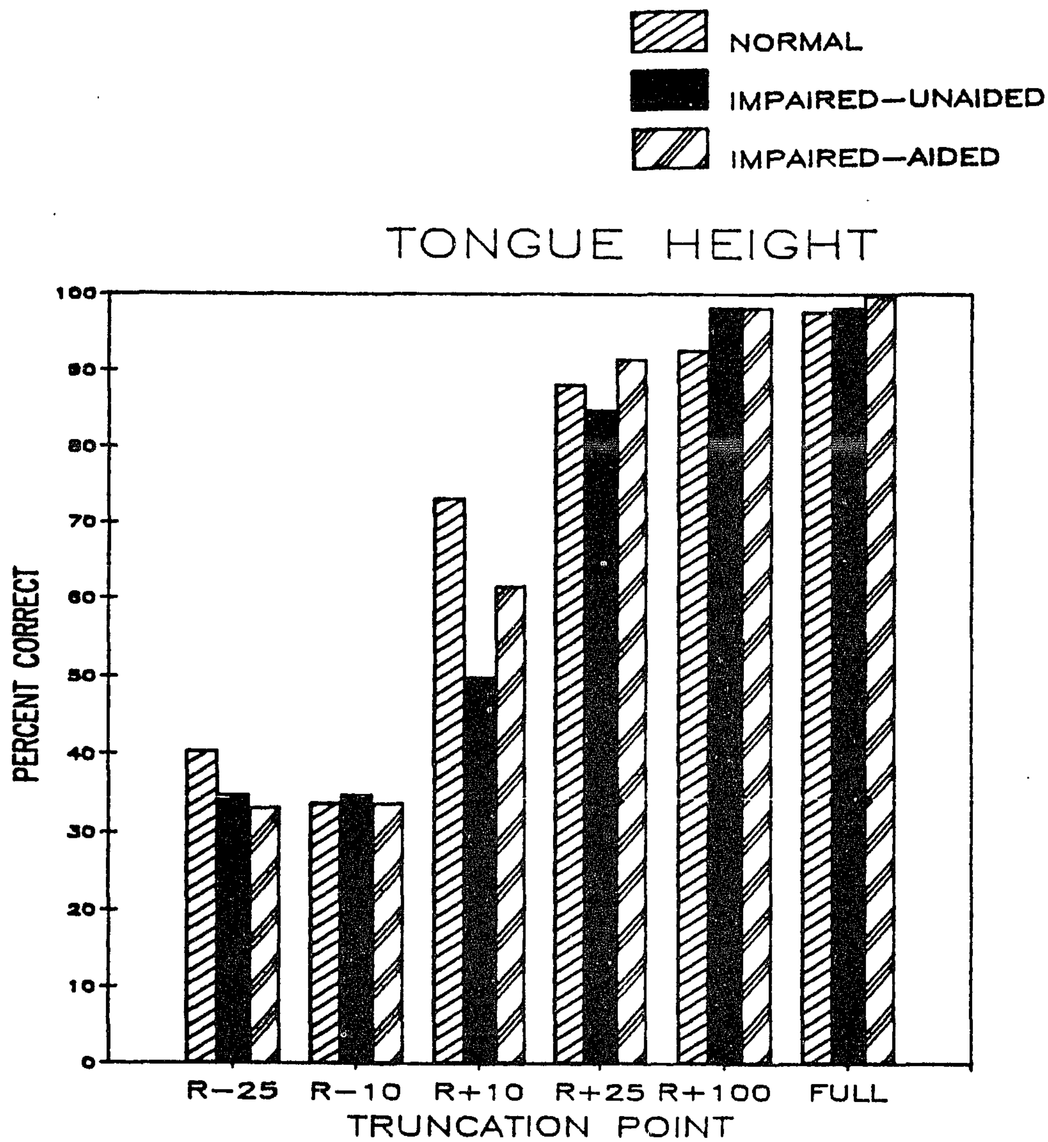

Figure 12: Percent correct Tongue Height identification averaged across the ten consonants at each truncation point. The parameter is group membership.

FIGURE 13

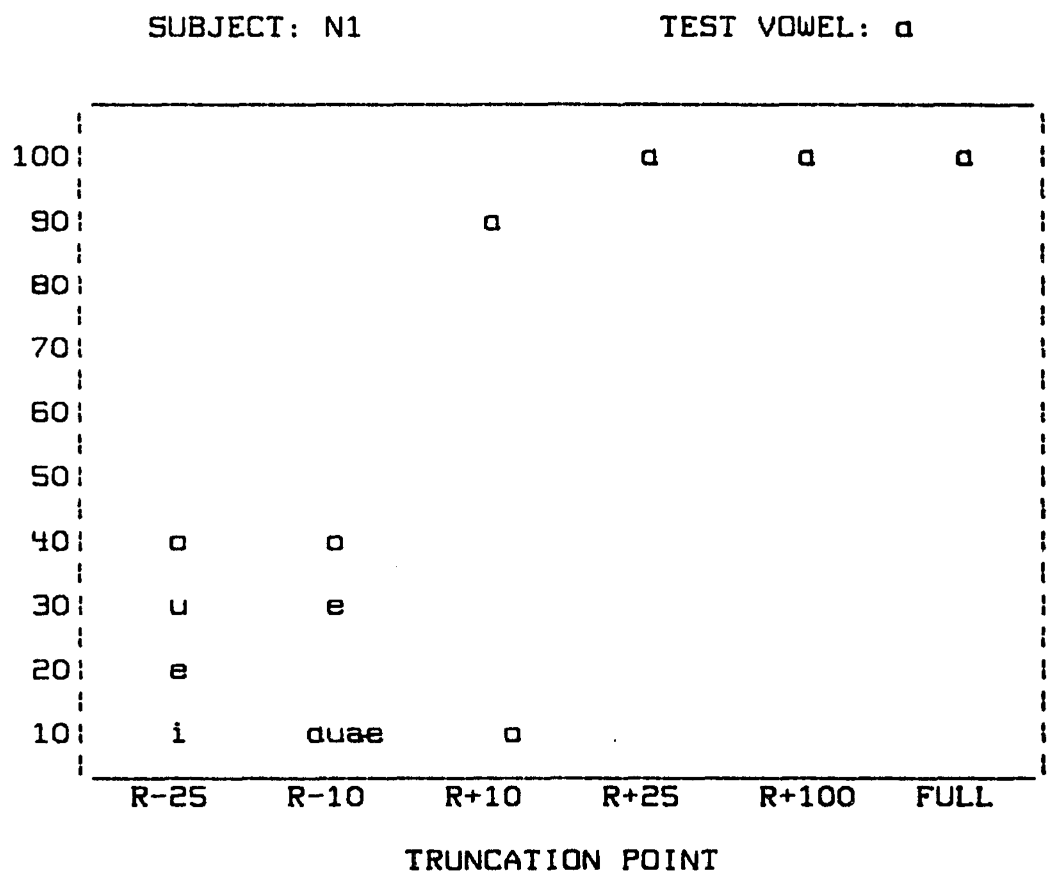

Figure 13: Response percentages to the /ɑ/ stimulus at each truncation point for N1.

FIGURE 14

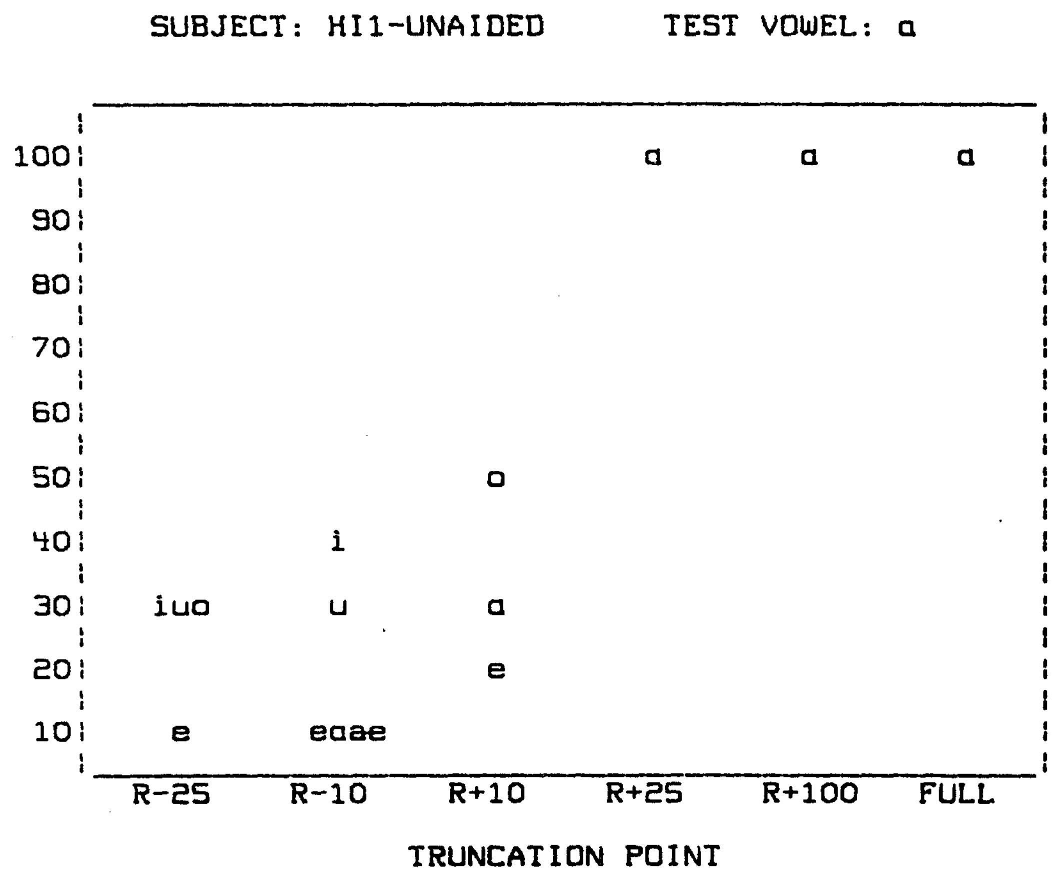

Figure 14: Response percentages to the /ɑ/ stimulus at each truncation point for HI1-Unaided.

FIGURE 15

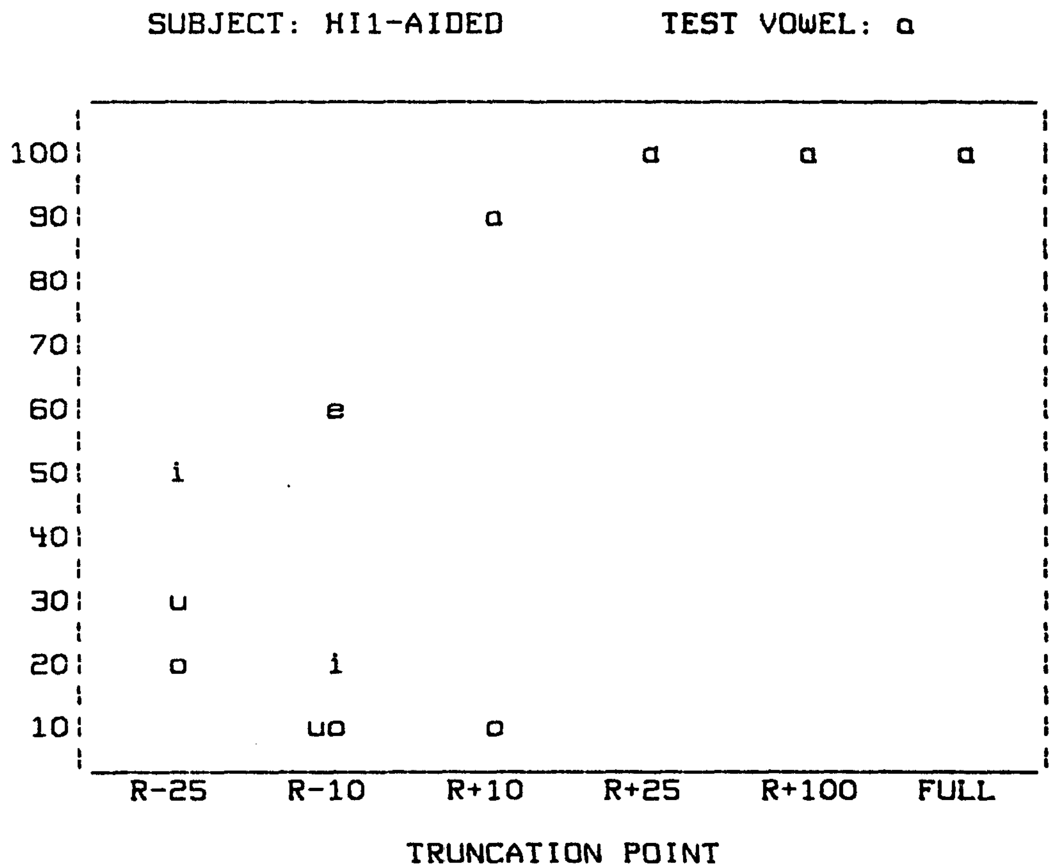

Figure 15: Response percentages to the /ɑ/ stimulus at each truncation point for HI1-Aided.

FIGURE 16

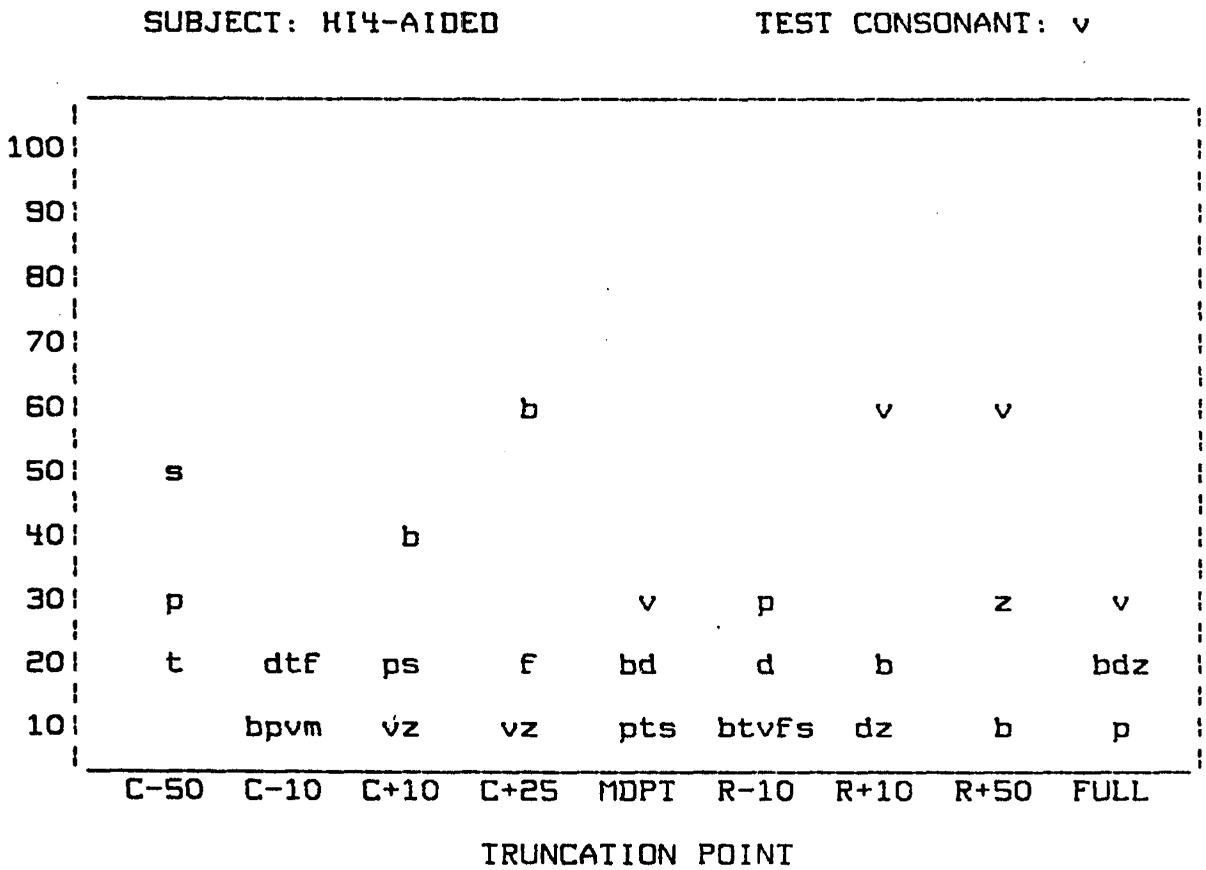

Figure 16: Response percentages to the /v/ stimulus at each truncation point for HI4-Aided.

FIGURE 17

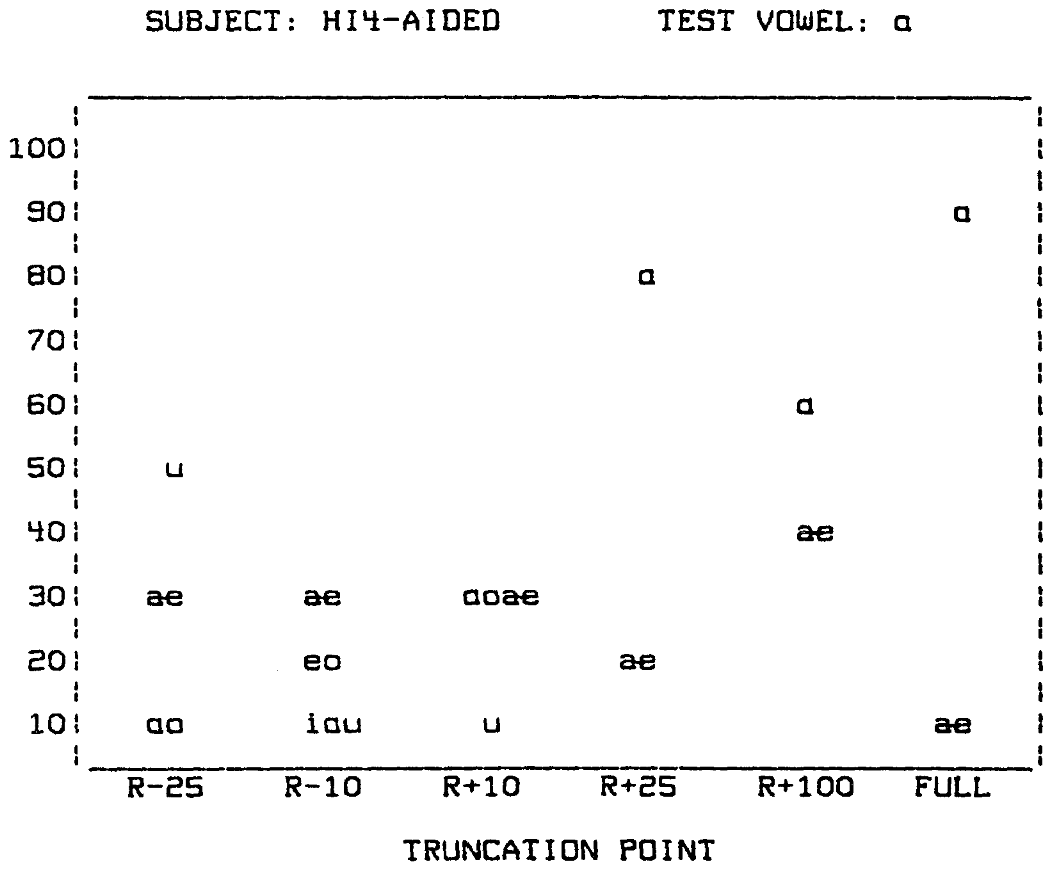

Figure 17: Response percentages to the /d/ stimulus at each truncation point for HI4-Aided.

APPENDIX A

Acoustic specifications of the test syllables.

Consonants

Phoneme	Fo range V1*	Duration V1	Closure-release duration	Closure-midpoint duration	V1-C F2 transition duration
b	124-120Hz	151.6ms	94.5ms	47.25ms	22.6ms
p	127-120Hz	130.8ms	153.4ms	76.7ms	16.7ms
d	127-118Hz	198.2ms	65.0ms	32.5ms	37.1ms
t	123-120Hz	168.3ms	113.6ms	56.8ms	21.1ms
v	128-120Hz	203.8ms	90.9ms	45.45ms	51.6ms
f	130-125Hz	147.5ms	166.6ms	83.3ms	40.9ms
z	128-118Hz	198.9ms	104.6ms	52.3ms	49.3ms
s	125-120Hz	164.3ms	169.4ms	84.7ms	25.6ms
m	129-124Hz	163.1ms	109.7ms	54.85ms	68.6ms
n	127-122Hz	206.1ms	97.2ms	48.6ms	55.4ms

Vowels

Phoneme	Fo range V*	VOT /b/	C-V F2 transition duration
i	117-110Hz	-15.6ms	32.7ms
e	115-107Hz	-14.7ms	30.2ms
ɑ	110-100Hz	-21.7ms	13.2ms
u	125-115Hz	-2.0ms	25.3ms
o	120-105Hz	10.0ms	17.9ms
ae	118-109Hz	-8.9ms	17.5ms

*All contours were falling in frequency.

APPENDIX B

Percent-correct responses for each subject, truncation time, and phoneme.

CONSONANTS

Phoneme: b

Subject	C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
N1	10	0	20	80	100	90	100	100	100
N2	10	0	90	80	100	70	100	90	100
N3	0	10	100	90	100	100	100	100	90
Unaided									
HI1	0	0	40	80	80	100	100	90	100
HI2	0	0	60	80	90	100	100	100	100
HI3	0	0	40	100	100	100	90	90	100
HI4									20
Aided									
HI1	0	0	90	100	100	100	100	100	100
HI2	10	10	70	100	90	100	100	100	90
HI3	10	10	40	100	80	90	100	100	100
HI4	0	10	10	0	10	20	60	60	60

Phoneme: p

Subject	C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
N1	20	20	70	80	90	100	90	100	100
N2	30	10	60	40	100	100	80	100	100
N3	10	0	100	100	100	100	100	100	100
Unaided									
HI1	80	80	90	100	80	100	70	70	100
HI2	60	20	20	10	10	40	40	0	0
HI3	30	60	20	40	50	30	60	10	10
HI4									10
Aided									
HI1	90	80	80	90	100	70	60	60	80
HI2	40	20	60	30	50	30	60	0	0
HI3	50	10	70	80	50	70	100	30	20
HI4	40	50	60	70	50	20	70	20	0

Phoneme: d

Subject	C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
N1	10	10	20	80	100	100	100	100	100
N2	10	0	90	100	100	100	100	100	100
N3	10	0	100	100	100	100	100	100	100
Unaided									
HI1	0	0	20	60	30	80	40	100	100
HI2	0	20	90	90	100	90	80	70	60
HI3	10	0	90	100	90	90	80	80	80
HI4									0
Aided									
HI1	0	0	90	90	80	90	100	100	100
HI2	0	70	60	90	100	100	100	100	100
HI3	10	10	90	70	100	100	100	100	100
HI4	0	0	10	10	0	10	10	80	80

Phoneme: t

Subject	C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
N1	0	90	100	100	100	90	100	100	100
N2	10	100	100	100	60	60	90	90	100
N3	20	90	100	80	80	50	100	100	90
Unaided									
HI1	0	30	20	30	30	50	100	80	100
HI2	20	30	20	40	0	20	70	50	40
HI3	20	20	10	10	10	30	0	30	30
HI4									20
Aided									
HI1	0	100	100	100	100	90	100	100	100
HI2	10	40	80	20	50	50	80	80	100
HI3	20	70	100	100	70	100	100	100	100
HI4	0	40	40	40	30	30	10	0	10

Phoneme: v

Subject	C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
N1	10	10	90	100	90	100	100	100	100
N2	50	30	90	100	90	100	100	100	100
N3	0	40	90	100	90	100	100	100	100
Unaided									
HI1	0	0	30	90	100	60	90	80	80
HI2	0	10	50	90	80	80	90	100	100
HI3	0	0	10	20	0	10	60	70	90
HI4									40
Aided									
HI1	0	30	100	90	100	100	100	100	100
HI2	0	10	80	90	90	80	100	90	100
HI3	0	20	60	90	70	90	90	90	90
HI4	0	10	10	10	30	10	60	60	30

Phoneme: f

Subject	C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
N1	20	20	90	90	100	100	100	100	100
N2	20	90	40	90	100	100	100	100	100
N3	0	10	10	70	70	100	100	100	100
Unaided									
HI1	30	100	90	100	100	100	100	100	100
HI2	0	0	0	10	0	30	60	80	60
HI3	40	30	40	50	60	60	80	80	90
HI4									20
Aided									
HI1	90	80	100	100	100	100	90	100	100
HI2	0	0	40	40	60	30	80	70	70
HI3	30	0	60	50	40	80	90	100	100
HI4	10	20	20	0	20	10	20	0	40

Phoneme: z

Subject	C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
N1	10	90	100	100	100	100	100	90	100
N2	0	80	100	80	100	100	80	100	100
N3	0	20	100	100	100	100	100	100	100
Unaided									
HI1	0	0	20	20	50	40	80	100	100
HI2	0	50	30	40	0	70	80	30	60
HI3	20	90	90	80	90	100	100	90	80
HI4									10
Aided									
HI1	0	0	0	0	10	100	100	100	100
HI2	0	40	30	30	40	70	90	70	100
HI3	0	80	80	100	90	80	70	100	90
HI4	10	80	90	100	90	80	50	80	80

Phoneme: s

Subject	C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
N1	10	60	10	70	100	100	100	100	100
N2	0	10	30	20	80	100	100	90	100
N3	0	50	30	60	100	90	100	100	100
Unaided									
HI1	0	0	0	0	100	100	100	100	100
HI2	0	10	40	100	50	70	60	30	60
HI3	10	30	0	10	0	20	10	20	50
HI4									10
Aided									
HI1	0	0	0	0	100	100	100	100	100
HI2	0	20	20	30	70	100	100	100	100
HI3	20	10	0	0	90	90	100	90	100
HI4	10	0	10	0	30	10	0	0	0

Phoneme: m

Subject	C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
N1	10	10	20	100	100	100	90	100	100
N2	60	20	20	100	100	100	100	100	100
N3	90	100	80	100	100	100	100	100	100
Unaided									
HI1	0	0	0	70	100	100	100	100	100
HI2	10	20	40	50	100	100	100	100	100
HI3	0	0	0	50	70	100	90	80	80
HI4									0
Aided									
HI1	50	80	80	100	100	100	100	100	100
HI2	20	30	40	80	100	90	100	100	100
HI3	20	10	10	80	100	100	100	100	80
HI4	30	20	30	30	0	20	10	20	10

Phoneme: n

Subject	C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
N1	30	0	10	100	100	100	100	100	100
N2	0	0	0	80	100	90	100	90	100
N3	0	0	20	100	100	100	100	100	100
Unaided									
HI1	0	0	50	80	80	100	100	100	100
HI2	0	10	70	90	90	100	100	100	90
HI3	30	10	60	90	20	90	100	90	100
HI4									40
Aided									
HI1	0	10	90	100	100	100	100	100	100
HI2	20	50	80	100	70	100	100	100	100
HI3	20	0	70	90	80	90	100	100	100
HI4	10	0	0	10	0	20	10	10	10

VOWELS

Phoneme: i

Subject	R-25	R-10	R+10	R+25	R+100	FULL
N1	0	0	100	100	100	100
N2	10	10	90	100	100	100
N3	0	0	100	100	100	90
Unaided						
HI1	10	20	20	100	100	100
HI2	10	10	10	100	100	100
HI3	40	20	30	10	100	100
HI4	30	0	10	20	70	90
Aided						
HI1	20	30	80	100	100	100
HI2	0	0	70	100	100	100
HI3	30	0	30	100	100	100
HI4	30	20	0	100	100	100

Phoneme: e

Subject	R-25	R-10	R+10	R+25	R+100	FULL
N1	10	0	0	90	70	100
N2	0	0	0	70	60	90
N3	0	0	0	70	60	100
Unaided						
HI1	20	10	0	70	100	100
HI2	0	0	0	20	80	100
HI3	50	20	40	50	30	100
HI4	10	20	20	10	100	100
Aided						
HI1	10	20	60	100	100	100
HI2	0	0	30	100	90	100
HI3	0	10	10	100	90	100
HI4	20	20	40	40	30	100

Phoneme: a

Subject	R-25	R-10	R+10	R+25	R+100	FULL
N1	0	10	90	100	100	100
N2	0	0	100	100	100	90
N3	10	30	70	100	100	90
Unaided						
HI1	0	10	30	100	100	100
HI2	10	30	60	80	70	40
HI3	10	10	20	90	60	80
HI4	0	30	20	60	30	20
Aided						
HI1	0	0	90	100	100	100
HI2	30	70	90	40	100	100
HI3	0	40	100	100	100	100
HI4	10	10	30	80	60	90

Phoneme: u

Subject	R-25	R-10	R+10	R+25	R+100	FULL
N1	60	60	100	100	100	100
N2	50	80	100	80	100	100
N3	70	80	100	80	100	100
Unaided						
HI1	30	50	70	80	100	100
HI2	30	70	90	90	100	90
HI3	10	10	70	80	100	100
HI4	0	10	10	10	50	100
Aided						
HI1	40	40	90	100	100	100
HI2	90	80	100	100	100	100
HI3	10	10	90	100	100	100
HI4	10	10	50	90	100	100

Phoneme: o

Subject	R-25	R-10	R+10	R+25	R+100	FULL
N1	50	0	80	90	100	100
N2	30	10	70	10	90	90
N3	20	10	90	100	90	100
Unaided						
HI1	40	10	80	50	90	100
HI2	30	0	30	100	100	100
HI3	30	10	0	40	80	90
HI4	10	10	10	50	80	80
Aided						
HI1	20	10	80	100	100	100
HI2	20	10	10	70	60	100
HI3	20	0	0	10	90	100
HI4	0	0	0	90	100	100

Phoneme: ae

Subject	R-25	R-10	R+10	R+25	R+100	FULL
N1	0	0	70	100	100	100
N2	10	0	80	100	100	100
N3	20	10	70	100	100	100
Unaided						
HI1	0	10	30	100	100	100
HI2	0	0	10	60	60	70
HI3	10	0	0	10	40	70
HI4	10	10	40	30	60	100
Aided						
HI1	0	0	0	80	100	100
HI2	0	10	10	100	100	100
HI3	0	10	20	90	100	100
HI4	0	10	10	90	100	100

APPENDIX C

Selection percentages for each response alternative, test phoneme, truncation time, and subject. The response alternative is shown first followed by the slection percentage in parenthesis. Response alternatives not shown were selected at a rate of 0% for that test phoneme.

CONSONANTS

Subject: N1 Test Phoneme: /b/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
v(50)	p(50)	p(80)	b(80)	b(100)	b(90)	b(100)	b(100)	b(100)
p(30)	f(30)	b(20)	p(10)		v(10)			
b(10)	v(20)		n(10)					
t(10)								

Subject: N1 Test Phoneme: /p/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
f(80)	f(50)	p(70)	p(80)	p(90)	p(100)	p(90)	p(100)	p(100)
p(20)	v(20)	f(30)	f(20)	v(10)		f(10)		
	p(20)							
	t(10)							

Subject: N1 Test Phoneme: /d/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
b(30)	t(90)	t(80)	d(80)	d(100)	d(100)	d(100)	d(100)	d(100)
p(20)	d(10)	d(20)	t(20)					
v(20)								
d(10)								
t(10)								
f(10)								

Subject: N1 Test Phoneme: /t/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(30)	t(90)	t(100)	t(100)	t(100)	t(90)	t(100)	t(100)	t(100)
f(30)	d(10)				d(10)			
d(20)								
v(20)								

Subject: N1 Test Phoneme: /v/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(70)	P(90)	v(90)	v(100)	v(90)	v(100)	v(100)	v(100)	v(100)
f(20)	v(10)	p(10)		b(10)				
v(10)								

Subject: N1 Test Phoneme: /f/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(80)	v(70)	f(90)	f(90)	f(100)	f(100)	f(100)	f(100)	f(100)
f(20)	f(20)	v(10)	v(10)					
	s(10)							

Subject: N1 Test Phoneme: /z/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
t(50)	z(90)	z(100)	z(100)	z(100)	z(100)	z(100)	z(90)	z(100)
s(20)	d(10)						v(10)	
p(10)								
d(10)								
z(10)								

Subject: N1 Test Phoneme: /s/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(30)	s(60)	t(60)	s(70)	s(100)	s(100)	s(100)	s(100)	s(100)
f(30)	t(30)	d(10)	t(20)					
b(10)	d(10)	v(10)	z(10)					
t(10)		s(10)						
z(10)		n(10)						
s(10)								

Subject: N1 Test Phoneme: /m/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
n(50)	p(40)	p(80)	m(100)	m(100)	m(100)	m(90)	m(100)	m(100)
v(30)	v(20)	m(20)				n(10)		
b(10)	n(20)							
m(10)	f(10)							
	m(10)							

Subject: N1 Test Phoneme: /n/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
v(30)	t(100)	t(60)	n(100)	n(100)	n(100)	n(100)	n(100)	n(100)
m(30)		d(30)						
n(30)		n(10)						
p(10)								

Subject: N2 Test Phoneme: /b/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
f(30)	v(60)	b(90)	b(80)	b(100)	b(70)	b(100)	b(90)	b(100)
t(20)	f(30)	v(10)	p(10)		v(30)		v(10)	
z(20)	p(10)		m(10)					
b(10)								
s(10)								
m(10)								

Subject: N2 Test Phoneme: /p/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(30)	f(60)	p(60)	p(40)	p(100)	p(100)	p(80)	p(100)	p(100)
m(30)	d(20)	f(40)	v(30)			f(20)		
b(10)	b(10)		b(20)					
t(10)	p(10)		f(10)					
v(10)								
s(10)								

Subject: N2 Test Phoneme: /d/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
v(30)	t(90)	d(90)	d(100)	d(100)	d(100)	d(100)	d(100)	d(100)
t(20)	p(10)	t(10)						
f(20)								
d(10)								
m(10)								
n(10)								

Subject: N2 Test Phoneme: /t/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
v(40)	t(100)	t(100)	t(100)	t(60)	t(60)	t(90)	t(90)	t(100)
p(20)				d(20)	f(30)	d(10)	n(10)	
b(10)				s(20)	d(10)			
d(10)								
t(10)								
f(10)								

Subject: N2 Test Phoneme: /v/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
v(50)	b(40)	v(90)	v(100)	v(90)	v(100)	v(100)	v(100)	v(100)
f(30)	v(30)	m(10)		b(10)				
b(20)	f(20)							
	p(10)							

Subject: N2 Test Phoneme: /f/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
t(30)	f(90)	f(40)	f(90)	f(100)	f(100)	f(100)	f(100)	f(100)
v(30)	v(10)	s(30)	v(10)					
f(20)		p(10)						
p(10)		d(10)						
d(10)		t(10)						

Subject: N2 Test Phoneme: /z/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
t(50)	z(80)	z(100)	z(80)	z(100)	z(100)	z(80)	z(100)	z(100)
d(20)	b(10)		t(10)			d(10)		
v(20)	d(10)		s(10)			s(10)		
f(10)								

Subject: N2 Test Phoneme: /s/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
t(30)	t(50)	s(30)	t(60)	s(80)	s(100)	s(100)	s(90)	s(100)
n(30)	p(10)	t(20)	s(20)	b(10)			z(10)	
b(10)	v(10)	p(10)	d(10)	z(10)				
p(10)	z(10)	d(10)	n(10)					
f(10)	s(10)	f(10)						
m(10)	n(10)	z(10)						
		n(10)						

Subject: N2 Test Phoneme: /m/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
m(60)	v(40)	v(60)	m(100)	m(100)	m(100)	m(100)	m(100)	m(100)
v(20)	p(20)	m(20)						
f(20)	f(20)	b(10)						
	m(20)	p(10)						

Subject: N2 Test Phoneme: /n/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
m(50)	d(80)	d(50)	n(80)	n(100)	n(90)	n(100)	n(90)	n(100)
f(30)	t(10)	t(40)	d(20)		m(10)		m(10)	
p(10)	z(10)	m(10)						
s(10)								

Subject: N3 Test Phoneme: /b/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(100)	p(70)	b(100)	b(90)	b(100)	b(100)	b(100)	b(100)	b(90)
	b(10)		d(10)					n(10)
	v(10)							
	f(10)							

Subject: N3 Test Phoneme: /p/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(80)	t(50)	p(70)	p(90)	f(80)	f(60)	p(100)	p(100)	p(100)
t(10)	p(40)	t(20)	v(10)	p(20)	p(40)			
m(10)	s(10)	d(10)						

Subject: N3 Test Phoneme: /d/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(80)	t(100)	d(100)	d(100)	d(100)	d(100)	d(100)	d(100)	d(100)
d(10)								
m(10)								

Subject: N3 Test Phoneme: /t/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(80)	t(90)	t(100)	t(80)	t(80)	t(50)	t(100)	t(100)	t(90)
t(20)	d(10)		d(20)	d(10)	f(40)			n(10)
				f(10)	d(10)			

Subject: N3 Test Phoneme: /v/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
t(40)	p(50)	v(90)	v(100)	v(90)	v(100)	v(100)	v(100)	v(100)
p(30)	v(40)	n(10)		f(10)				
d(20)	b(10)							
f(10)								

Subject: N3 Test Phoneme: /f/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(90)	p(80)	p(90)	f(70)	f(70)	f(100)	f(100)	f(100)	f(100)
t(10)	f(10)	f(10)	t(20)	v(20)				
	s(10)		v(10)	n(10)				

Subject: N3 Test Phoneme: /z/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
d(40)	d(70)	z(100)	z(100)	z(100)	z(100)	z(100)	z(100)	z(100)
t(40)	z(20)							
v(20)	n(10)							

Subject: N3 Test Phoneme: /s/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
m(80)	s(50)	t(30)	s(60)	s(100)	s(90)	s(100)	s(100)	s(100)
p(10)	t(20)	s(30)	t(30)		n(10)			
t(10)	p(10)	d(20)	z(10)					
	z(10)	n(20)						
	n(10)							

Subject: N3 Test Phoneme: /m/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
m(90)	m(100)	m(80)	m(100)	m(100)	m(100)	m(100)	m(100)	m(100)
n(10)		v(20)						

Subject: N3 Test Phoneme: /n/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
m(100)	d(80)	d(80)	n(100)	n(100)	n(100)	n(100)	n(100)	n(100)
	t(20)	n(20)						

Subject: HI1-Unaided Test Phoneme: /b/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
f(80)	p(90)	p(60)	b(80)	b(80)	b(100)	b(100)	b(90)	b(100)
p(10)	f(10)	b(40)	p(10)	p(10)			d(10)	
t(10)			v(10)	v(10)				

Subject: HI1-Unaided Test Phoneme: /p/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(80)	p(100)	p(90)	p(100)	p(80)	p(100)	p(70)	p(70)	p(100)
f(20)		t(10)		f(20)		f(20)	f(30)	
						t(10)		

Subject: HI1-Unaided Test Phoneme: /d/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(50)	t(60)	t(40)	d(60)	v(40)	d(80)	d(40)	d(100)	d(100)
f(40)	f(20)	v(40)	v(40)	d(30)	t(10)	f(30)		
v(10)	p(10)	d(20)		t(20)	v(10)	t(20)		
	v(10)			p(10)		v(10)		

Subject: HI1-Unaided Test Phoneme: /t/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(100)	p(50)	p(40)	p(40)	f(50)	t(50)	t(100)	t(80)	t(100)
	t(30)	f(30)	t(30)	t(30)	p(30)		s(20)	
	f(20)	t(20)	f(30)	p(10)	f(20)			
		s(10)		s(10)				

Subject: HI1-Unaided Test Phoneme: /v/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(100)	f(80)	f(40)	v(90)	v(100)	v(60)	v(90)	v(80)	v(80)
	p(20)	p(30)	b(10)		f(20)	b(10)	b(20)	b(10)
		v(30)			b(10)			z(10)
					p(10)			

Subject: HI1-Unaided Test Phoneme: /f/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(60)	f(100)	f(90)	f(100)	f(100)	f(100)	f(100)	f(100)	f(100)
f(30)		s(10)						
v(10)								

Subject: HI1-Unaided Test Phoneme: /z/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(90)	v(90)	v(80)	v(80)	v(50)	v(60)	z(80)	z(100)	z(100)
f(10)	f(10)	z(20)	z(20)	z(50)	z(40)	v(20)		

Subject: HI1-Unaided — Test Phoneme: /s/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
f(100)	f(100)	f(100)	f(100)	s(100)	s(100)	s(100)	s(100)	s(100)

Subject: HI1-Unaided — Test Phoneme: /m/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
f(60)	p(80)	p(60)	m(70)	m(100)	m(100)	m(100)	m(100)	m(100)
t(30)	v(10)	v(20)	v(20)					
n(10)	f(10)	f(20)	n(10)					

Subject: HI1-Unaided — Test Phoneme: /n/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(60)	t(80)	n(50)	n(80)	n(80)	n(100)	n(100)	n(100)	n(100)
f(40)	f(20)	v(30)	t(10)	v(20)				
		t(10)	v(10)					
		f(10)						

Subject: HI2-Unaided — Test Phoneme: /b/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
m(40)	p(70)	b(60)	b(80)	b(90)	b(100)	b(100)	b(100)	b(100)
n(20)	t(30)	d(30)	d(20)	d(10)				
p(10)		m(10)						
t(10)								
v(10)								
f(10)								

Subject: HI2-Unaided — Test Phoneme: /p/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(60)	t(50)	t(70)	t(90)	t(90)	t(60)	t(60)	f(100)	f(100)
t(30)	p(20)	p(20)	p(10)	p(10)	p(40)	p(40)		
m(10)	m(20)	s(10)						
	n(10)							

Subject: HI2-Unaided — Test Phoneme: /d/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(60)	t(70)	d(90)	d(90)	d(100)	d(90)	d(80)	d(70)	d(60)
t(40)	d(20)	b(10)	n(10)		b(10)	b(20)	b(30)	b(40)
	p(10)							

Subject: HI2-Unaided — Test Phoneme: /t/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(70)	p(60)	p(80)	p(50)	p(70)	p(60)	t(70)	p(50)	p(50)
t(20)	t(30)	t(20)	t(40)	b(10)	t(20)	p(30)	t(50)	t(40)
d(10)	f(10)		b(10)	d(10)	b(10)			s(10)
				n(10)	n(10)			

Subject: HI2-Unaided Test Phoneme: /v/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(50)	d(70)	v(50)	v(90)	v(80)	v(80)	v(90)	v(100)	v(100)
t(40)	t(10)	z(50)	t(10)	z(10)	z(10)	z(10)		
d(10)	v(10)			s(10)	s(10)			
	z(10)							

Subject: HI2-Unaided Test Phoneme: /f/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(50)	p(50)	t(70)	t(40)	s(50)	s(60)	f(60)	f(80)	f(60)
t(50)	t(50)	s(30)	s(40)	t(40)	f(30)	s(40)	v(10)	s(30)
			p(10)	v(10)	t(10)		s(10)	v(10)
			f(10)					

Subject: HI2-Unaided Test Phoneme: /z/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
d(20)	z(50)	v(40)	z(40)	v(60)	z(70)	z(80)	v(60)	z(60)
t(20)	v(30)	z(30)	v(30)	s(40)	v(30)	s(10)	z(30)	v(30)
s(20)	s(10)	s(30)	s(30)			n(10)	s(10)	s(10)
m(20)	n(10)							
v(10)								
n(10)								

Subject: HI2-Unaided Test Phoneme: /s/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
m(70)	t(30)	s(40)	s(100)	s(50)	s(70)	s(60)	f(50)	s(60)
n(30)	m(30)	f(30)		f(30)	f(20)	f(30)	s(30)	f(30)
	n(20)	v(20)		v(20)	v(10)	v(10)	v(20)	v(10)
	f(10)	n(10)						
	s(10)							

Subject: HI2-Unaided Test Phoneme: /m/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(60)	t(50)	m(40)	m(50)	m(100)	m(100)	m(100)	m(100)	m(100)
t(30)	p(30)	t(30)	n(50)					
m(10)	m(20)	d(20)						
		n(10)						

Subject: HI2-Unaided Test Phoneme: /n/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(80)	t(60)	n(70)	n(90)	n(90)	n(100)	n(100)	n(100)	n(90)
t(10)	d(20)	m(20)	m(10)	m(10)				m(10)
m(10)	m(10)	d(10)						
	n(10)							

Subject: HI3-Unaided — Test Phoneme: /b/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(30)	p(40)	b(40)	b(100)	b(100)	b(100)	b(90)	b(90)	b(100)
d(30)	d(20)	v(20)				v(10)	d(10)	
t(20)	v(20)	f(20)						
v(20)	z(10)	d(10)						
	s(10)	s(10)						

Subject: HI3-Unaided — Test Phoneme: /p/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
t(40)	p(60)	t(30)	p(40)	p(50)	p(30)	p(60)	f(90)	f(90)
p(30)	d(10)	f(30)	t(30)	d(20)	t(30)	b(10)	p(10)	p(10)
v(20)	t(10)	p(20)	f(30)	t(10)	f(30)	t(10)		
n(10)	s(10)	z(20)		f(10)	b(10)	v(10)		
	n(10)			m(10)		z(10)		

Subject: HI3-Unaided — Test Phoneme: /d/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
f(40)	t(80)	d(90)	d(100)	d(90)	d(90)	d(80)	d(80)	d(80)
b(20)	p(20)	z(10)		b(10)	b(10)	b(10)	b(20)	b(20)
p(20)						t(10)		
d(10)								
s(10)								

Subject: HI3-Unaided — Test Phoneme: /t/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(20)	p(40)	p(40)	p(40)	p(50)	p(30)	p(80)	p(60)	p(50)
d(20)	t(20)	z(20)	z(20)	b(10)	t(30)	d(10)	t(30)	t(30)
t(20)	f(20)	d(10)	t(10)	d(10)	f(20)	m(10)	d(10)	f(20)
z(20)	d(10)	t(10)	v(10)	t(10)	b(10)			
v(10)	v(10)	f(10)	f(10)	v(10)	z(10)			
n(10)		s(10)	s(10)	n(10)				

Subject: HI3-Unaided — Test Phoneme: /v/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
t(50)	t(30)	d(40)	z(60)	d(30)	z(80)	v(60)	v(70)	v(90)
d(30)	f(20)	z(20)	v(20)	t(30)	d(10)	z(40)	z(30)	d(10)
p(20)	s(20)	p(10)	p(10)	z(20)	v(10)			
	b(10)	t(10)	d(10)	b(10)				
	p(10)	v(10)		s(10)				
	z(10)	n(10)						

Subject: HI3-Unaided Test Phoneme: /f/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
f(40)	p(50)	f(40)	f(50)	f(60)	f(60)	f(80)	f(80)	f(90)
z(20)	f(30)	p(30)	p(20)	d(10)	t(20)	p(10)	s(20)	s(10)
p(10)	b(10)	v(20)	t(20)	t(10)	d(10)	z(10)		
t(10)	t(10)	s(10)	s(10)	v(10)	s(10)			
s(10)				m(10)				
m(10)								

Subject: HI3-Unaided Test Phoneme: /z/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
f(30)	z(90)	z(90)	z(80)	z(90)	z(100)	z(100)	z(90)	z(80)
d(20)	d(10)	v(10)	v(20)	d(10)			v(10)	v(20)
t(20)								
z(20)								
p(10)								

Subject: HI3-Unaided Test Phoneme: /s/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
t(50)	p(50)	p(30)	f(70)	f(40)	f(60)	f(30)	f(70)	f(50)
p(10)	s(30)	d(20)	z(20)	p(30)	s(20)	p(20)	s(20)	s(50)
d(10)	t(10)	v(20)	s(10)	z(20)	t(10)	b(10)	t(10)	
z(10)	f(10)	z(20)		b(10)	m(10)	t(10)		
s(10)		t(10)				z(10)		
m(10)						s(10)		
						n(10)		

Subject: HI3-Unaided Test Phoneme: /m/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
s(30)	p(30)	v(40)	m(50)	m(70)	m(100)	m(90)	m(80)	m(80)
d(20)	f(30)	d(30)	n(20)	n(30)		n(10)	n(20)	n(20)
v(20)	d(20)	p(20)	b(10)					
p(10)	t(10)	t(10)	d(10)					
t(10)	s(10)		f(10)					

Subject: HI3-Unaided Test Phoneme: /n/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
d(30)	t(70)	n(60)	n(90)	m(40)	n(90)	n(100)	n(90)	n(100)
n(30)	d(10)	d(20)	m(10)	f(30)	m(10)		m(10)	
b(10)	v(10)	z(20)		n(20)				
f(10)	n(10)			v(10)				
z(10)								
m(10)								

Subject: HI4-Unaided Test Phoneme: /b/

Truncation Time								
C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
								v(50)
								b(20)
								d(10)
								z(10)
								m(10)

Subject: HI4-Unaided Test Phoneme: /p/

Truncation Time								
C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
								z(30)
								s(20)
								b(10)
								p(10)
								v(10)
								f(10)
								n(10)

Subject: HI4-Unaided Test Phoneme: /d/

Truncation Time								
C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
								m(40)
								b(20)
								n(20)
								v(10)
								t(10)

Subject: HI4-Unaided Test Phoneme: /t/

Truncation Time								
C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
								d(20)
								t(20)
								z(20)
								n(20)
								b(10)
								f(10)

Subject: HI4-Unaided Test Phoneme: /v/

Truncation Time								
C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
								v(40)
								p(20)
								d(20)
								f(20)

Subject: HI4-Unaided Test Phoneme: /f/

Truncation Time								
C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
								n(30)
								p(20)
								f(20)
								z(20)
								t(10)

Subject: HI4-Unaided Test Phoneme: /z/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
								d(30)
								v(30)
								p(10)
								z(10)
								s(10)
								m(10)

Subject: HI4-Unaided Test Phoneme: /s/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
								t(30)
								f(30)
								z(20)
								v(10)
								s(10)

Subject: HI4-Unaided Test Phoneme: /m/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
								v(30)
								b(20)
								z(20)
								t(10)
								f(10)
								n(10)

Subject: HI4-Unaided Test Phoneme: /n/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
								n(40)
								p(20)
								t(10)
								z(10)
								s(10)
								n(10)

Subject: HI1-Aided Test Phoneme: /b/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(60)	p(90)	b(90)	b(100)	b(100)	b(100)	b(100)	b(100)	b(100)
f(40)	f(10)	p(10)						

Subject: HI1-Aided Test Phoneme: /p/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(90)	p(80)	p(80)	p(90)	p(100)	p(70)	p(60)	p(60)	p(80)
f(10)	b(10)	f(20)	f(10)		f(20)	t(40)	f(40)	f(20)
	n(10)				v(10)			

Subject: HI1-Aided Test Phoneme: /d/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(70)	t(100)	d(90)	d(90)	d(80)	d(90)	d(100)	d(100)	d(100
f(20)		t(10)	t(10)	v(20)	t(10)			
t(10)								

Subject: HI-Aided Test Phoneme: /t/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(100)	t(100)	t(100)	t(100)	t(100)	t(90)	t(100)	t(100)	t(100)
					p(10)			

Subject: HI1-Aided Test Phoneme: /v/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(100)	p(50)	v(100)	v(90)	v(100)	v(100)	v(100)	v(100)	v(100)
	v(30)		d(10)					
	b(20)							

Subject: HI1-Aided Test Phoneme: /f/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
f(90)	f(80)	f(100)	f(100)	f(100)	f(100)	f(90)	f(100)	f(100)
p(10)	p(10)					p(10)		
	t(10)							

Subject: HI1-Aided Test Phoneme: /z/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
f(40)	v(100)	v(100)	v(100)	v(90)	z(100)	z(100)	z(100)	z(100)
p(30)				z(10)				
v(20)								
t(10)								

Subject: HI1-Aided Test Phoneme: /s/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
f(60)	f(100)	f(100)	f(100)	s(100)	s(100)	s(100)	s(100)	s(100)
p(30)								
m(10)								

Subject: HI1-Unaided Test Phoneme:/m/

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
m(50)	m(80)	m(80)	m(100)	m(100)	m(100)	m(100)	m(100)	m(100)
p(30)	p(20)	p(20)						
v(10)								
f(10)								

Subject: HI1-Aided — Test Phoneme: /n/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(50)	d(60)	n(90)	n(100)	n(100)	n(100)	n(100)	n(100)	n(100)
f(20)	t(20)	d(10)						
m(20)	v(10)							
b(10)	n(10)							

Subject: HI2-Aided — Test Phoneme: /b/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
f(50)	p(40)	b(70)	b(100)	b(90)	b(100)	b(100)	b(100)	b(90)
b(10)	d(40)	p(20)		p(10)				d(10)
p(10)	b(10)	n(10)						
t(10)	t(10)							
v(10)								
n(10)								

Subject: HI2-Aided — Test Phoneme: /p/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
b(40)	t(50)	p(60)	f(50)	p(50)	p(30)	p(60)	f(60)	f(70)
p(40)	p(20)	t(20)	p(30)	t(20)	t(30)	t(30)	t(30)	v(20)
t(10)	d(20)	v(20)	t(20)	f(10)	f(30)	b(10)	v(10)	t(10)
m(10)	b(10)			s(10)	b(10)			
				n(10)				

Subject: HI2-Aided — Test Phoneme: /d/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(40)	d(70)	d(60)	d(90)	d(100)	d(100)	d(100)	d(100)	d(100)
m(30)	t(30)	t(30)	t(10)					
b(20)		p(10)						
t(10)								

Subject: HI2-Aided — Test Phoneme: /t/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(60)	d(60)	t(80)	d(80)	d(50)	d(50)	t(80)	t(80)	t(100)
m(20)	t(40)	d(20)	t(20)	t(50)	t(50)	d(20)	d(20)	
b(10)								
t(10)								

Subject: HI2-Aided — Test Phoneme: /v/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
b(40)	d(40)	v(80)	v(90)	v(90)	v(80)	v(100)	v(90)	v(100)
p(30)	p(20)	f(20)	z(10)	d(10)	z(20)		z(10)	
d(30)	t(20)							
	b(10)							
	v(10)							

Subject: HI2-Aided   Test Phoneme: /f/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(70)	p(50)	f(40)	f(40)	f(60)	s(60)	f(80)	f(70)	f(70)
m(20)	t(30)	v(30)	t(30)	p(10)	f(30)	v(10)	v(20)	v(30)
n(10)	b(20)	t(20)	v(20)	d(10)	v(10)	n(10)	n(10)	
		b(10)	b(10)	v(10)				
				s(10)				

Subject: HI2-Aided   Test Phoneme: /z/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
f(40)	v(60)	v(60)	v(50)	v(50)	z(70)	z(90)	z(70)	z(100)
p(20)	z(40)	z(30)	z(30)	z(40)	v(20)	v(10)	v(30)	
v(20)		s(10)	f(10)	s(10)	s(10)			
b(10)			s(10)					
s(10)								

Subject: HI2-Aided   Test Phoneme: /s/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
n(60)	f(40)	f(30)	f(60)	s(70)	s(100)	s(100)	s(100)	s(100)
f(20)	s(20)	v(20)	s(30)	f(20)				
p(10)	n(20)	s(20)	v(10)	v(10)				
m(10)	t(10)	n(20)						
	z(10)	z(10)						

Subject: HI2-Aided   Test Phoneme: /m/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(20)	p(30)	m(40)	m(80)	m(100)	m(90)	m(100)	m(100)	m(100)
d(20)	m(30)	p(30)	p(10)		n(10)			
m(20)	b(20)	b(10)	n(10)					
n(20)	d(10)	d(10)						
t(10)	n(10)	n(10)						
f(10)								

Subject: HI2-Aided   Test Phoneme: /n/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
m(40)	n(50)	n(80)	n(100)	n(70)	n(100)	n(100)	n(100)	n(100)
p(20)	d(20)	d(20)		m(30)				
n(20)	t(20)							
b(10)	p(10)							
t(10)								

Subject: HI3-Aided   Test Phoneme: /b/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(30)	p(50)	b(40)	b(100)	b(80)	b(90)	b(100)	b(100)	b(100)
t(20)	f(20)	f(20)		d(20)	v(10)			
v(20)	b(10)	p(10)						
f(20)	t(10)	d(10)						
b(10)	s(10)	t(10)						
		m(10)						

Subject: HI3-Aided Test Phoneme: /p/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(50)	t(20)	p(70)	p(80)	p(50)	p(70)	p(100)	f(70)	f(80)
d(30)	z(20)	f(20)	t(10)	b(10)	v(20)		p(30)	p(20)
v(10)	s(20)	z(10)	f(10)	d(10)	z(10)			
z(10)	p(10)			t(10)				
	d(10)			v(10)				
	v(10)			s(10)				
	f(10)							

Subject: HI3-Aided Test Phoneme: /d/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
f(30)	t(90)	d(90)	d(70)	d(100)	d(100)	d(100)	d(100)	d(100)
p(20)	d(10)	t(10)	v(20)					
b(10)			z(10)					
d(10)								
t(10)								
v(10)								
z(10)								

Subject: HI3-Aided Test Phoneme: /t/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(50)	t(70)	t(100)	t(100)	t(70)	t(100)	t(100)	t(100)	t(100)
t(20)	p(20)			p(20)				
v(10)	d(10)			d(10)				
f(10)								
z(10)								

Subject: HI3-Aided Test Phoneme: /v/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(30)	p(30)	v(60)	v(90)	v(70)	v(90)	v(90)	v(90)	v(90)
f(30)	f(30)	z(20)	b(10)	b(10)	z(10)	b(10)	b(10)	b(10)
d(20)	v(20)	b(10)		d(10)				
b(10)	d(10)	t(10)		m(10)				
m(10)	t(10)							

Subject: HI3-Aided Test Phoneme: /f/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(40)	p(50)	f(60)	f(50)	f(40)	f(80)	f(90)	f(100)	f(100)
f(30)	s(20)	t(30)	p(20)	p(30)	p(10)	p(10)		
t(20)	b(10)	s(10)	d(10)	t(20)	s(10)			
s(10)	d(10)		v(10)	v(10)				
	t(10)		s(10)					

Subject: HI3-Aided Test Phoneme: /z/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(40)	z(80)	z(80)	z(100)	z(90)	z(80)	z(70)	z(100)	z(90)
v(20)	v(10)	v(20)		v(10)	d(10)	v(30)		v(10)
b(10)	n(10)				v(10)			
d(10)								
t(10)								
f(10)								

Subject: HI3-Aided Test Phoneme: /s/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
t(30)	p(60)	p(60)	p(30)	s(90)	s(90)	s(100)	s(90)	s(100)
p(20)	t(10)	d(20)	d(20)	t(10)	z(10)		z(10)	
s(20)	f(10)	t(10)	b(10)					
b(10)	z(10)	z(10)	t(10)					
d(10)	s(10)		v(10)					
f(10)			f(10)					
			z(10)					

Subject: HI3-Aided Test Phoneme: /m/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
n(30)	p(30)	v(30)	m(80)	m(100)	m(100)	m(100)	m(100)	m(80)
v(20)	f(20)	b(20)	p(10)					s(10)
m(20)	b(10)	p(20)	n(10)					n(10)
b(10)	t(10)	d(10)						
p(10)	z(10)	f(10)						
d(10)	m(10)	m(10)						
	n(10)							

Subject: HI3-Aided Test Phoneme: /n/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
d(50)	d(60)	n(70)	n(90)	n(80)	n(90)	n(100)	n(100)	n(100)
n(20)	t(20)	d(30)	m(10)	s(10)	m(10)			
b(10)	v(10)			m(10)				
t(10)	z(10)							
v(10)								

Subject: HI4-Aided Test Phoneme: /b/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
s(90)	p(50)	p(30)	v(50)	s(40)	b(20)	b(60)	b(60)	b(60)
z(10)	b(10)	v(30)	d(20)	p(20)	p(20)	f(20)	v(30)	v(20)
	d(10)	f(20)	p(10)	v(20)	f(20)	z(10)	n(10)	d(10)
	f(10)	b(10)	t(10)	b(10)	z(20)	n(10)		n(10)
	z(10)	t(10)	s(10)	f(10)	v(10)			
	s(10)				s(10)			

Subject: HI4-Aided — Test Phoneme: /p/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(40)	p(50)	p(60)	p(70)	p(50)	t(30)	p(70)	b(40)	b(20)
t(30)	d(10)	f(20)	t(20)	t(30)	p(20)	t(10)	v(30)	t(20)
f(20)	t(10)	z(10)	m(10)	d(10)	n(20)	z(10)	p(20)	v(20)
m(10)	z(10)	n(10)		s(10)	d(10)	m(10)	m(10)	d(10)
	m(10)				f(10)			f(10)
	n(10)				m(10)			z(10)
								m(10)

Subject: HI4-Aided — Test Phoneme: /d/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(40)	t(70)	t(50)	t(60)	t(80)	t(70)	t(40)	d(80)	d(80)
t(40)	p(10)	s(20)	d(10)	s(20)	p(10)	f(20)	b(10)	t(10)
f(10)	f(10)	p(10)	f(10)		d(10)	s(20)	v(10)	f(10)
s(10)	s(10)	d(10)	z(10)		s(10)	p(10)		
		f(10)	s(10)			d(10)		

Subject: HI4-Aided — Test Phoneme: /t/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(50)	p(40)	t(40)	t(40)	p(40)	p(30)	p(40)	b(50)	v(40)
m(30)	t(40)	p(20)	f(30)	t(30)	t(30)	t(10)	p(20)	m(20)
f(10)	z(10)	f(20)	p(10)	n(20)	v(10)	v(10)	v(10)	t(10)
n(10)	n(10)	s(20)	v(10)	s(10)	z(10)	f(10)	f(10)	f(10)
			n(10)		s(10)	s(10)	n(10)	z(10)
					m(10)	m(10)		n(10)
						n(10)		

Subject: HI4-Aided — Test Phoneme: /v/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
s(50)	d(20)	b(40)	b(60)	v(30)	p(30)	v(60)	v(60)	v(30)
p(30)	t(20)	p(20)	f(20)	b(20)	d(20)	b(20)	z(30)	b(20)
t(20)	f(20)	s(20)	v(10)	d(20)	b(10)	d(10)	b(10)	d(20)
	b(10)	v(10)	z(10)	p(10)	t(10)	z(10)		z(20)
	p(10)	z(10)		t(10)	v(10)			p(10)
	v(10)			s(10)	f(10)			
	m(10)				s(10)			

Subject: HI4-Aided — Test Phoneme: /f/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
m(30)	p(20)	n(60)	m(50)	m(40)	m(60)	b(20)	v(60)	f(40)
p(20)	t(20)	f(20)	p(20)	p(20)	p(10)	p(20)	b(10)	s(20)
t(20)	f(20)	p(10)	n(20)	f(20)	v(10)	t(20)	p(10)	p(10)
f(10)	n(20)	v(10)	t(10)	t(10)	f(10)	f(20)	d(10)	t(10)
z(10)	v(10)			s(10)	z(10)	d(10)	m(10)	v(10)
n(10)	m(10)					v(10)		m(10)

Subject: HI4-Aided — Test Phoneme: /z/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(40)	z(80)	z(90)	z(100)	z(90)	z(80)	z(50)	z(80)	z(80)
t(20)	s(10)	s(10)		f(10)	v(10)	d(20)	s(20)	v(10)
s(20)	n(10)				f(10)	v(20)		s(10)
f(10)						s(10)		
z(10)								

Subject: HI4-Aided — Test Phoneme: /s/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
p(40)	f(30)	t(20)	n(30)	s(30)	t(20)	v(60)	v(60)	v(40)
t(20)	n(30)	m(20)	t(20)	v(20)	v(20)	m(20)	z(30)	z(30)
n(20)	p(20)	n(20)	v(20)	f(20)	f(20)	f(10)	b(10)	t(20)
s(10)	t(10)	p(10)	p(10)	p(10)	m(20)	z(10)		f(10)
m(10)	z(10)	f(10)	f(10)	t(10)	s(10)			
		z(10)	m(10)	n(10)	n(10)			
		s(10)						

Subject: HI4-Aided — Test Phoneme: /m/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
t(40)	n(30)	b(30)	m(30)	b(40)	b(40)	b(80)	b(70)	b(50)
f(30)	t(20)	m(30)	v(20)	v(20)	m(20)	v(10)	m(20)	v(20)
m(30)	v(20)	d(20)	b(20)	n(20)	d(10)	m(10)	v(10)	d(10)
	m(20)	v(10)	d(10)	d(10)	v(10)			t(10)
	f(10)	n(10)	f(10)	f(10)	f(10)			m(10)
			z(10)		n(10)			

Subject: HI4-Aided — Test Phoneme: /n/

Truncation Time

C-50	C-10	C+10	C+25	MDPT	R-10	R+10	R+50	FULL
t(40)	t(40)	t(50)	d(40)	d(40)	t(70)	d(70)	v(30)	v(30)
f(20)	s(20)	z(20)	z(20)	t(30)	n(20)	b(10)	b(20)	b(20)
s(20)	b(10)	b(10)	t(10)	b(10)	p(10)	z(10)	d(20)	m(20)
p(10)	p(10)	p(10)	v(10)	p(10)		n(10)	z(10)	d(10)
n(10)	d(10)	d(10)	f(10)	f(10)			m(10)	t(10)
	z(10)		n(10)				n(10)	n(10)

VOWELS

Subject: N1 Test Phoneme: ee

Truncation

R-25	R-10	R+10	R+25	R+100	Full
a(30)	oo(50)	ee(100)	ee(100)	ee(100)	ee(100)
o(30)	o(20)				
ah(20)	ae(20)				
oo(20)	ah(10)				

Subject: N1 Test Phoneme: a

Truncation

R-25	R-10	R+10	R+25	R+100	Full
ae(50)	oo(70)	ae(100)	a(90)	a(70)	a(100)
ah(20)	0(20)		ae(10)	ae(30)	
a(10)	ee(10)				
oo(10)					
o(10)					

Subject: N1 Test Phoneme: ah

Truncation

R-25	R-10	R+10	R+25	R+100	Full
o(40)	o(40)	ah(90)	ah(100)	ah(100)	ah(100)
oo(30)	a(30)	o(10)			
a(20)	ah(10)				
ee(10)	ae(10)				

Subject: N1 Test Phoneme: oo

Truncation

R-25	R-10	R+10	R+25	R+100	Full
oo(60)	oo(60)	oo(100)	oo(100)	oo(100)	oo(100)
o(30)	ae(20)				
a(10)	a(10)				
	o(10)				

Subject: N1 Test Phoneme: o

Truncation

R-25	R-10	R+10	R+25	R+100	Full
o(50)	oo(70)	o(80)	o(90)	o(100)	o(100)
ah(40)	ah(20)	oo(20)	ah(10)		
oo(10)	ae(10)				

Subject: N1 Test Phoneme: ae

Truncation

R-25	R-10	R+10	R+25	R+100	Full
a(30)	oo(50)	ae(70)	ae(100)	ae(100)	ae(100)
ah(30)	ah(20)	a(30)			
ee(20)	o(20)				
oo(20)	ee(10)				

Subject: N2 Test Phoneme: ee

Truncation

R-25	R-10	R+10	R+25	R+100	Full
oo(80)	oo(70)	ee(90)	ee(100)	ee(100)	ee(100)
ee(10)	o(20)	oo(10)			

ae(10)	ee(10)

Subject: N2 Test Phoneme: a

Truncation

R-25	R-10	R+10	R+25	R+100	Full
oo(60)	oo(60)	ae(80)	a(70)	a(60)	a(90)
ee(30)	ee(30)	ee(10)	ae(30)	ae(30)	o(10)
O(10)	ah(10)	ah(10)		oo(10)	

Subject: N2 Test Phoneme: ah

Truncation

R-25	R-10	R+10	R+25	R+100	Full
oo(70)	oo(60)	ah(100)	ah(100)	ah(100)	ah(90)
ee(30)	ee(20)				oo(10)
	o(10)				
	ae(10)				

Subject: N2 Test Phoneme: oo

Truncation

R-25	R-10	R+10	R+25	R+100	Full
oo(50)	oo(80)	oo(100)	oo(80)	oo(100)	oo(100)
ee(20)	ee(20)		ah(10)		
o(20)			o(10)		
ah(10)					

Subject: N2 Test Phoneme: o

Truncation

R-25	R-10	R+10	R+25	R+100	Full
oo(70)	oo(80)	o(70)	ah(90)	o(90)	o(90)
o(30)	ah(10)	oo(30)	o(10)	ah(10)	ah(10)
	o(10)				

Subject: N2 Test Phoneme: ae

Truncation

R-25	R-10	R+10	R+25	R+100	Full
oo(80)	oo(60)	ae(80)	ae(100)	ae(100)	ae(100)
ee(10)	ee(30)	ee(10)			
ae(10)	o(10)	oo(10)			

Subject: N3 Test Phoneme: ee

Truncation

R-25	R-10	R+10	R+25	R+100	Full
oo(70)	oo(90)	ee(100)	ee(100)	ee(100)	ee(90)
a(10)	o(10)				ae(10)
ae(10)					
ah(10)					

Subject: N3 Test Phoneme: a

Truncation

R-25	R-10	R+10	R+25	R+100	Full
ah(70)	oo(70)	ae(80)	a(70)	a(60)	a(100)
o(10)	ah(20)	ah(20)	ae(30)	ae(30)	
oo(10)	o(10)			oo(10)	
ae(10)					

Subject: N3 Test Phoneme: ah

Truncation

R-25	R-10	R+10	R+25	R+100	Full
oo(60)	oo(50)	ah(70)	ah(100)	ah(100)	ah(90)
ae(30)	ah(30)	o(30)			ee(10)
ah(10)	a(10)				
	ae(10)				

Subject: N3 Test Phoneme: oo

Truncation

R-25	R-10	R+10	R+25	R+100	Full
oo(70)	oo(80)	oo(100)	oo(80)	oo(100)	oo(100)
ae(20)	a(10)		o(10)		
ah(10)	ah(10)		ah(10)		

Subject: N3 Test Phoneme: o

Truncation

R-25	R-10	R+10	R+25	R+100	Full
oo(40)	oo(80)	o(90)	o(100)	o(90)	o(100)
o(20)	o(10)	oo(10)		ah(10)	
ae(20)	ah(10)				
ah(20)					

Subject: N3 Test Phoneme: ae

Truncation

R-25	R-10	R+10	R+25	R+100	Full
oo(60)	oo(80)	ae(70)	ae(100)	ae(100)	ae(100)
ae(20)	a(10)	a(30)			
ah(20)	ae(10)				

Subject: HI1-Unaided Test Phoneme: ee

Truncation

R-25	R-10	R+10	R+25	R+100	Full
oo(50)	oo(30)	oo(80)	ee(100)	ee(100)	ee(100)
ee(10)	ee(20)	ee(20)			
a(10)	a(20)				
ah(10)	ah(10)				
o(10)	o(10)				
ae(10)	ae(10)				

Subject: HI1-Unaided Test Phoneme: a

Truncation

R-25	R-10	R+10	R+25	R+100	Full
ae(30)	ee(30)	ah(50)	a(70)	a(100)	a(100)
ee(20)	oo(30)	ee(30)	o(20)		
a(20)	o(30)	o(20)	ae(10)		
oo(20)	a(10)				
ah(10)					

Subject: HI1-Unaided Test Phoneme: ah

Truncation

R-25	R-10	R+10	R+25	R+100	Full
ee(30)	ee(40)	o(50)	ah(100)	ah(100)	ah(100)
oo(30)	oo(30)	ah(30)			
o(30)	a(10)	a(20)			
a(10)	ah(10)				
	ae(10)				

Subject: HI1-Unaided Test Phoneme: oo

Truncation

R-25	R-10	R+10	R+25	R+100	Full
a(30)	oo(50)	oo(70)	oo(80)	oo(100)	oo(100)
oo(30)	ee(40)	o(20)	o(20)		
ee(20)	a(10)	a(10)			
ae(20)					

Subject: HI1-Unaided Test Phoneme: o

Truncation

R-25	R-10	R+10	R+25	R+100	Full
oo(50)	oo(70)	o(80)	ah(50)	o(90)	o(100)
o(40)	a(10)	oo(20)	o(50)	ah(10)	
a(10)	o(10)				
	ae(10)				

Subject: HI1-Unaided Test Phoneme: ae

Truncation

R-25	R-10	R+10	R+25	R+100	Full
ee(60)	oo(50)	o(50)	ae(100)	ae(100)	ae(100)
oo(30)	ee(20)	ae(30)			
o(10)	o(20)	a(10)			
	ae(10)	ah(10)			

Subject: HI2-Unaided Test Phoneme: ee

Truncation

R-25	R-10	R+10	R+25	R+100	Full
a(40)	ah(70)	oo(40)	ee(100)	ee(100)	ee(100)
ah(30)	a(10)	ae(30)			
ee(10)	ee(10)	a(20)			
o(10)	oo(10)	ee(10)			
oo(10)					

Subject: HI2-Unaided Test Phoneme: a

Truncation

R-25	R-10	R+10	R+25	R+100	Full
ah(60)	oo(40)	o(70)	o(80)	a(80)	a(100)
ae(20)	ee(20)	oo(30)	a(20)	o(20)	
ee(10)	o(20)				
o(10)	ah(20)				

Subject: HI2-Unaided Test Phoneme: ah

Truncation

R-25	R-10	R+10	R+25	R+100	Full
oo(50)	ah(30)	ah(6o)	ah(80)	ah(70)	ae(60)
a(20)	a(20)	o(30)	ae(20)	ae(30)	ah(40)
ee(20)	o(20)	ae(10)			
ah(10)	ae(20)				
	oo(10)				

Subject: HI2-Unaided Test Phoneme: oo

Truncation

R-25	R-10	R+10	R+25	R+100	Full
ae(40)	oo(70)	oo(90)	oo(90)	oo(100)	oo(90)
oo(30)	ee(20)	a(10)	ee(10)		o(10)
ee(20)	ah(10)				
ah(10)					

Subject: HI2-Unaided Test Phoneme: o

Truncation

R-25	R-10	R+10	R+25	R+100	Full
o(30)	oo(90)	oo(70)	o(100)	o(100)	o(100)
ah(30)	ah(10)	o(30)			
a(20)					
oo(20)					

Subject: HI2-Unaided Test Phoneme: ae

Truncation

R-25	R-10	R+10	R+25	R+100	Full
ah(70)	ah(70)	o(80)	ae(60)	ae(60)	ae(70)
ee(30)	oo(20)	ae(10)	ah(30)	ah(40)	ah(30)
	ee(10)	ah(10)	a(10)		

Subject: HI3-Unaided Test Phoneme: ee

Truncation

R-25	R-10	R+10	R+25	R+100	Full
ee(40)	a(30)	ee(30)	oo(40)	ee(100)	ee(100)
a(40)	o(30)	ae(30)	a(20)		
ae(20)	ee(20)	a(20)	ah(20)		
	ah(10)	oo(20)	ee(10)		
	ae(10)		ae(10)		

Subject: HI3-Unaided Test Phoneme: a

Truncation

R-25	R-10	R+10	R+25	R+100	Full
a(50)	ee(30)	a(40)	a(50)	o(70)	a(100)
ee(30)	a(20)	oo(40)	ee(20)	a(30)	
ae(20)	ae(20)	ee(10)	oo(20)		
	ah(10)	ae(10)	ah(10)		
	oo(10)				
	o(10)				

Subject: HI3-Unaided Test Phoneme: ah

Truncation

R-25	R-10	R+10	R+25	R+100	Full
oo(40)	oo(30)	ee(30)	ah(90)	ah(60)	ah(80)
a(30)	ee(20)	o(30)	ee(10)	ae(40)	ae(20)
ee(10)	a(20)	ah(20)			
ah(10)	ah(10)	ae(20)			
ae(10)	o(10)				
	ae(10)				

Subject: HI3-Unaided Test Phoneme: oo

Truncation

R-25	R-10	R+10	R+25	R+100	Full
ee(40)	ae(30)	oo(70)	oo(80)	oo(100)	oo(100)
ae(30)	a(20)	ee(10)	a(10)		
ah(20)	ah(20)	a(10)	ae(10)		
oo(10)	ee(10)	ae(10)			
	oo(10)				
	o(10)				

Subject: HI3-Unaided Test Phoneme: o

Truncation

R-25	R-10	R+10	R+25	R+100	Full
a(30)	ae(40)	oo(60)	o(40)	o(80)	o(90)
o(30)	a(30)	ae(20)	a(20)	ah(20)	ee(10)
ah(20)	ah(10)	ee(10)	ee(10)		
ee(10)	oo(10)	a(10)	ah(10)		
ae(10)	o(10)		oo(10)		
			ae(10)		

Subject: HI3-Unaided Test Phoneme: ae

Truncation

R-25	R-10	R+10	R+25	R+100	Full
ee(30)	a(40)	a(40)	ah(80)	ah(60)	ae(70)
oo(20)	ee(30)	ee(30)	a(10)	ae(40)	ah(20)
o(20)	ah(20)	o(20)	ae(10)		ee(10)
a(10)	oo(10)	ah(10)			
ah(10)					
ae(10)					

Subject: HI4-Unaided Test Phoneme: ee

Truncation

R-25	R-10	R+10	R+25	R+100	Full
ee(30)	ae(30)	oo(30)	ee(20)	ee(70)	ee(90)
a(20)	a(20)	a(20)	a(20)	a(20)	a(10)
ah(20)	ah(20)	ah(20)	oo(20)	oo(10)	
oo(20)	o(20)	ae(20)	o(20)		
ae(10)	oo(10)	ee(10)	ae(20)		

Subject: HI4-Unaided Test Phoneme: a

Truncation

R-25	R-10	R+10	R+25	R+100	Full
ah(40)	ae(30)	oo(50)	ee(30)	a(100)	a(100)
ae(30)	a(20)	a(20)	oo(30)		
ee(10)	oo(20)	ah(20)	ah(20)		
a(10)	o(20)	ee(10)	a(10)		
o(10)			o(10)		

Subject: HI4-Unaided Test Phoneme: ah

Truncation

R-25	R-10	R+10	R+25	R+100	Full
a(60)	ah(30)	a(40)	ah(60)	ae(60)	ae(80)
ee(10)	ae(30)	ee(20)	ae(40)	ah(30)	ah(20)
oo(10)	oo(20)	ah(20)		o(10)	
o(10)	ee(10)	o(20)			
ae(10)	a(10)				

Subject: HI4-Unaided Test Phoneme: oo

Truncation

R-25	R-10	R+10	R+25	R+100	Full
o(40)	ah(30)	a(30)	ae(30)	oo(50)	oo(100)
ah(30)	a(20)	ee(20)	ah(20)	ae(20)	
a(20)	o(20)	ah(20)	o(20)	ee(10)	
ae(10)	ee(10)	oo(10)	ee(10)	ah(10)	
	oo(10)	o(10)	a(10)	o(10)	
	ae(10)	ae(10)	oo(10)		

Subject: HI4-Unaided Test Phoneme: o

Truncation

R-25	R-10	R+10	R+25	R+100	Full
ah(30)	oo(40)	ee(40)	o(50)	o(80)	o(80)
a(20)	ae(30)	ah(20)	oo(20)	ah(10)	a(20)
ae(20)	a(10)	a(10)	ae(20)	ae(10)	
ee(10)	ah(10)	oo(10)	a(10)		
oo(10)	o(10)	o(10)			
o(10)		ae(10)			

Subject: HI4-Unaided Test Phoneme: ae

Truncation

R-25	R-10	R+10	R+25	R+100	Full
a(40)	oo(30)	ae(40)	o(60)	ae(60)	ae(100)
oo(30)	o(30)	ee(20)	ae(30)	ah(40)	
ah(10)	ee(20)	a(20)	ah(10)		
o(10)	ah(10)	oo(20)			
ae(10)	ae(10)				

Subject: HI1-Aided Test Phoneme: ee

Truncation

R-25	R-10	R+10	R+25	R+100	Full
ee(20)	oo(40)	ee(80)	ee(100)	ee(100)	ee(100)
a(20)	ee(30)	oo(20)			
oo(20)	a(20)				
ae(20)	ah(10)				
ah(10)					
o(10)					

Subject: HI1-Aided Test Phoneme: a

Truncation

R-25	R-10	R+10	R+25	R+100	Full
ee(50)	ee(40)	a(60)	a(100)	a(100)	a(100)
oo(30)	oo(40)	ae(30)			
a(10)	a(20)	o(10)			
o(10)					

Subject: HI1-Aided Test Phoneme: ah

Truncation

R-25	R-10	R+10	R+25	R+100	Full
ee(50)	a(60)	ah(90)	ah(100)	ah(100)	ah(100)
oo(30)	ee(20)	o(10)			
o(20)	oo(10)				
	o(10)				

Subject: HI1-Aided Test Phoneme: oo

Truncation

R-25	R-10	R+10	R+25	R+100	Full
oo(40)	ee(50)	oo(90)	oo(100)	oo(100)	oo(100)
ee(20)	oo(40)	ee(10)			
a(20)	o(10)				
o(10)					
ae(10)					

Subject: HI1-Aided Test Phoneme: o

Truncation

R-25	R-10	R+10	R+25	R+100	Full
a(60)	oo(50)	o(80)	o(100)	o(100)	o(100)
o(20)	ee(20)	a(10)			
oo(10)	a(20)	oo(10)			
ae(10)	o(10)				

Subject: HI1-Aided Test Phoneme: ae

Truncation

R-25	R-10	R+10	R+25	R+100	Full
ee(50)	oo(60)	a(100)	ae(80)	ae(100)	ae(100)
a(20)	ee(20)		a(20)		
oo(20)	a(10)				
o(10)	o(10)				

Subject: HI2-Aided Test Phoneme: ee

Truncation

R-25	R-10	R+10	R+25	R+100	Full
ah(40)	ah(60)	ee(70)	ee(100)	ee(100)	ee(100)
oo(30)	o(20)	oo(30)			
a(10)	oo(20)				
o(10)					
ae(10)					

Subject: HI2-Aided Test Phoneme: a

Truncation

R-25	R-10	R+10	R+25	R+100	Full
ah(70)	oo(90)	ae(40)	a(100)	a(90)	a(100)
oo(20)	ee(10)	a(30)		o(10)	
ee(10)		o(30)			

Subject: HI2-Aided Test Phoneme: ah

Truncation

R-25	R-10	R+10	R+25	R+100	Full
oo(40)	ah(70)	ah(90)	ae(60)	ah(100)	ah(100)
ah(30)	ee(10)	o(10)	ah(40)		
o(20)	oo(10)				
ee(10)	ae(10)				

Subject: HI2-Aided Test Phoneme: oo

Truncation

R-25	R-10	R+10	R+25	R+100	Full
oo(90)	oo(80)	oo(100)	oo(100)	oo(100)	oo(100)
o(10)	ee(20)				

Subject: HI2-Aided Test Phoneme: o

Truncation

R-25	R-10	R+10	R+25	R+100	Full
ah(70)	oo(70)	oo(90)	o(70)	o(60)	o(100)
o(20)	ah(20)	o(10)	ah(30)	a(40)	
oo(10)	o(10)				

Subject: HI2-Aided Test Phoneme: ae

Truncation

R-25	R-10	R+10	R+25	R+100	Full
ah(90)	ah(60)	a(80)	ae(100)	ae(100)	ae(100)
oo(10)	o(20)	ae(10)			
	oo(10)	ah(10)			
	ae(10)				

Subject: HI3-Aided Test Phoneme: ee

Truncation

R-25	R-10	R+10	R+25	R+100	Full
ee(30)	a(40)	ee(30)	ee(100)	ee(100)	ee(100)
a(20)	ah(20)	oo(30)			
o(20)	ae(20)	ae(20)			
ae(20)	oo(10)	a(10)			
oo(10)	o(10)	ah(10)			

Subject: HI3-Aided — Test Phoneme: a

Truncation

R-25	R-10	R+10	R+25	R+100	Full
ee(40)	oo(60)	ae(70)	a(100)	a(90)	a(100)
ae(30)	ee(20)	ah(20)		ae(10)	
ah(20)	a(10)	a(10)			
oo(10)	ae(10)				

Subject: HI3-Aided — Test Phoneme: ah

Truncation

R-25	R-10	R+10	R+25	R+100	Full
ee(50)	ee(40)	ah(100)	ah(100)	ah(100)	ah(100)
oo(30)	ah(40)				
o(10)	a(10)				
ae(10)	o(10)				

Subject: HI3-Aided — Test Phoneme: oo

Truncation

R-25	R-10	R+10	R+25	R+100	Full
ee(40)	ae(30)	oo(90)	oo(100)	oo(100)	oo(100)
ah(20)	ee(20)	ah(10)			
o(20)	a(20)				
oo(10)	ah(20)				
ae(10)	oo(10)				

Subject: HI3-Aided — Test Phoneme: o

Truncation

R-25	R-10	R+10	R+25	R+100	Full
ae(40)	ae(60)	oo(80)	ah(90)	o(90)	o(100)
a(20)	ee(10)	ee(10)	o(10)	ah(10)	
ah(20)	ah(10)	a(10)			
0(20)	oo(10)				
	a(10)				

Subject: HI3-Aided — Test Phoneme: ae

Truncation

R-25	R-10	R+10	R+25	R+100	Full
ee(70)	ee(50)	ee(30)	ae(90)	ae(100)	ae(100)
a(30)	a(20)	a(30)	a(10)		
	ah(10)	ah(20)			
	o(10)	ae(20)			
	ae(10)				

Subject: HI4-Aided — Test Phoneme: ee

Truncation

R-25	R-10	R+10	R+25	R+100	Full
ee(30)	ah(40)	a(40)	ee(100)	ee(100)	ee(100)
a(30)	ee(20)	ae(40)			
oo(30)	o(20)	oo(20)			
ae(10)	ae(20)				

Subject: HI4-Aided | Test Phoneme: a

Truncation					
R-25	R-10	R+10	R+25	R+100	Full
ah(60)	ae(30)	a(40)	a(40)	ae(70)	a(100)
a(20)	a(20)	ae(40)	oo(20)	a(30)	
ae(20)	oo(20)	o(20)	ae(20)		
	ee(10)		ee(10)		
	ah(10)		ah(10)		
	o(10)				

Subject: HI4-Aided | Test Phoneme: ah

Truncation					
R-25	R-10	R+10	R+25	R+100	Full
oo(50)	ae(30)	ah(30)	ah(80)	ah(60)	ah(90)
ae(30)	a(20)	o(30)	ae(20)	ae(40)	ae(10)
ah(10)	o(20)	ae(30)			
o(10)	ee(10)	oo(10)			
	ah(10)				
	oo(10)				

Subject: HI4-Aided | Test Phoneme: oo

Truncation					
R-25	R-10	R+10	R+25	R+100	Full
a(40)	ae(30)	oo(50)	oo(90)	oo(100)	oo(100)
ae(30)	ee(20)	a(40)	o(10)		
ee(10)	a(20)	ah(10)			
oo(10)	ah(10)				
o(10)	oo(10)				
	o(10)				

Subject: HI4-Aided | Test Phoneme: o

Truncation					
R-25	R-10	R+10	R+25	R+100	Full
a(30)	ae(40)	oo(90)	o(90)	o(100)	o(100)
ah(30)	a(30)	ah(10)	ah(10)		
ae(30)	ah(20)				
oo(10)	ee(10)				

Subject: HI4-Aided | Test Phoneme: ae

Truncation					
R-25	R-10	R+10	R+25	R+100	Full
ah(40)	ah(30)	oo(40)	ae(90)	ae(100)	ae(100)
a(30)	oo(30)	o(40)	a(10)		
oo(20)	ee(20)	ee(10)			
ee(10)	a(10)	ae(10)			
	ae(10)				

VITA

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Current Status:
Doctoral Student and Alumni Federation Graduate Fellow--Louisiana State University

Clinical Audiologist--Associates III Hearing, Speech & Learning Center, Baton Rouge

Professional Interests:
Speech perception in the hearing impaired,
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Educational History:
B.S., Speech and Hearing Science, University of Illinois, 1982
M.A., Audiology, University of Iowa, 1984
Certificate of Clinical Competence--Audiology, 1988

Research Grants:
Collins, M.J. (Principle Investigator), & Schum, D. (Co-investigator). (1985). Clinical validation of low-frequency hearing loss. 3rd year renewal, Deafness Research Foundation.

Publications:
Hawkins, B., & Schum, D. (1985). Some effects of FM-system coupling on hearing aid characteristics. Journal of Speech and Hearing Disorders, 50, 132-141.

Hawkins, D., & Schum, D. (1984). Relationships among various measures of hearing aid gain. Journal of Speech and Hearing Disorders, 49, 94-97.

Schum, D. (1986). Inter-subject variability effects on the use of coupler-to-real-ear correction curves. Hearing Instruments, 37, 25-26.

Books (In Preparation):
Collins, M.J., & Schum, D. Hearing aids: A clinician's handbook. Med-Ed Press.

<u>Presentations</u>:

Collins, M.J., Hurtig, R., Besing, J., & Schum, D. (1985). Identification of voicing contrasts via the tactile mode. Paper presented at the Fall Meeting of the Acoustical Society of America, Nashville.

Collins, M.J., Schum, D., Yanda, J., & Fryauf-Bertschy, H. (1985). Low-frequency hearing loss: Benefits from three types of linear amplification. Paper presented at the Annual Convention of the American Speech-Language-Hearing Association, Washington.

Collins, M.J., Yanda, J., Fryauf, H., & Schum, D. (1984). Downward spread of masking and low-frequency hearing loss. Paper presented at the Fall Meeting of the Acoustical Society of America, Minneapolis.

Hawkins, D., & Schum, D. (1984). Electroacoustic characteristics of hearing aids and FM system-hearing aid combinations. Paper presented at the Annual Convention of the American Speech-Language-Hearing Association, San Francisco.

Schum, D., & Besing, J. (1987). Categorical phoneme identification functions in CV and CVCVCV segments. Paper presented at the Annual Convention of the American Speech-Language-Hearing Association, New Orleans.

Schum, D., & Collins, M.J. (1987). Spectral shaping options for persons with low- anf high-frequency sensorineural hearing loss. Paper pesented at the Spring Meeting of the Acoustical Society of America, Indianapolis.

Schum, D., & Collins, M.J. (1985). Test-retest reliability of two paired comparison hearing aid evaluation procedures. Paper presented at the Annual Convention of the American Speech-Language-Hearing Association, Washington.

Schum, D., Hawkins, D., & Collins, M.J. (1984). A comparison of various gain/frequency response schemes. Paper presented at the Annual Convention of the American Speech-Language-Hearing Association, San Francisco.

Schum, D., & Hurtig, R. (1985). Reaction times to categorically perceived speech stimuli. paer presented at the Fall Meeting of the Acoustical Society of America, Nashville.

Teaching Experience:

Audiologic Evaluation, Fall semester, 1985, LSU.

Rehabilitative Audiology, Spring semester, 1986, LSU.

Adult Rehabilitative Audiology, Spring semester, 1987, LSU.

Amplification for the Hearing Impaired, Fall semester, 1987, LSU. Fall semester, 1987, Louisiana State University School of Medicine, New Orleans.

DOCTORAL EXAMINATION AND DISSERTATION REPORT

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Major Field: Speech - Audiology

Title of Dissertation: The Time Course of Acoustic/Phonemic Cue Integration in the Sensorineural Hearing Impaired

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