INTELLIGIBILITY OF TIME-ALTERED CNC MONOSYLLABLES AS A FUNCTION OF CONTRALATERAL MASKING

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ABSTRACT

INTELLIGIBILITY OF TIME-ALTERED CNC MONOSYLLABLES AS A FUNCTION OF CONTRALATERAL MASKING

By

Dan F. Konkle

Previous research has suggested that time compressed versions of the Northwestern University Auditory Test No. 6 (NU-6) of speech discrimination had clinical potential as a measure of central auditory function. Clinical audiometric procedures, however, frequently require the use of contralateral masking in order to minimize non-test ear influences on the behavioral responses obtained from the ear under test. Currently, the effect of contralateral masking on the intelligibility of time compressed NU-6 words is unknown. The purpose of this investigation, therefore, was to examine the relationship between contralateral masking and the intelligibility of temporally accelerated NU-6 word lists.

Ninety normal hearing young adult listeners were administered Form B of the NU-6 test (time compressed by 0%, 30%, and 60%) under four different types of contralateral maskers (white noise, speech noise, a four chain multitalker passage, and the multitalker passage 60% time compressed). The intensity level of the NU-6 words was held constant at

75 dB SPL; whereas, contralateral maskers were presented at 30 dB, 60 dB, and 90 dB SPL. An equal number of right and left ears were tested for each experimental condition.

Subjects' responses were converted to percent correct scores and submitted to a multiple linear regression analysis with percent correct score regressed on masker intensity level, degree of time compression, ear, masker type, and combinations of these basic variables. Results from this investigation revealed that neither white noise nor speech noise had a significant effect upon NU-6 word intelligibility, regardless of the degree of NU-6 time-compression or the intensity level of the masker. Conversely, the multitalker maskers were found to cause a statistically significant decrease in percent correct scores when these stimuli were combined with other variables (i.e., time-compression, masker intensity level, and ear).

The findings from this investigation support the clinical utility of white noise and speech noise as contralateral maskers of time compressed speech stimuli. Additional research, however, should be conducted in order to generalize such observations to pathological populations. Results observed with the multitalker maskers served to illustrate a speech perceptual process characterized by an input filter. Moreover, the significant reduction in percent correct scores noted when multitalker maskers were combined with other variables suggested that input filtering may be bound by temporal parameters.

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CHAPTER I

INTRODUCTION

The Northwestern University Auditory Test No. 6 (NU-6), originally developed by Tillman and Carhart (1966) as a measure of phonemic discrimination, has been used in several recent investigations concerned with temporal acceleration (time-compression) and speech intelligibility. These investigations have provided information about the effects of time compression on the intelligibility of NU-6 stimuli for normal hearing young adults (Beasley, Forman, and Rintelmann, 1972a; Beasley, Schwimmer, and Rintelmann, 1972b; Riensche, Konkle, and Beasley, 1975), aging persons who possessed normal speech discrimination for non-accelerated stimuli (Konkle, Beasley, and Bess, 1975), and adults with sensorineural hearing loss (Kurdziel, Rintelmann, and Beasley, 1975). Based on these findings, it has been recommended that time-compressed versions of the NU-6 be used as a clinical test of central auditory function.

In clinical populations, however, it is frequently necessary to use contralateral masking in order to avoid the influence of non-test ear participation on audiometric results. Since there have been no published reports concerned with the effects of contralateral masking on the intelligibility of

time compressed NU-6 words, the interaction between masking the non-test ear and performance with time-compressed NU-6 stimuli are unknown. It was the purpose of this investigation, therefore, to examine the effects of contralateral masking on the intelligibility of temporally accelerated NU-6 word lists.

Time-Compressed Speech as a Test of Central Auditory Function

The central auditory system (CAS), defined by Jerger (1973, p. 86) "... as that portion of the total auditory system lying within the central nervous system," is comprised of a complex arrangement of neurological structures. Several investigators (Jerger, 1960, 1964; Katz, 1969; Willeford, 1969; Bergman, 1971) have noted that the complexity of the CAS provided an internal redundancy such that pure tone and conventional speech audiometric stimuli resulted in near normal responses despite neurological damage to the central auditory system. Consequently, investigators have sought to develop measures specifically designed to evaluate central auditory function.

Research on the development of central auditory tests has revealed that speech stimuli, modified to reduce external message redundancy, were the most suitable means to evaluate central auditory processing (Bocca, Calearo, and Cassinari, 1954; Bocca, Calearo, Cassinari, and Migliavacca, 1955; Bocca, 1955, 1956, 1958, 1961; Calearo, 1957; Calearo and Lazzaroni, 1957; Calearo and Antonelli, 1963). These inves-

tigators observed that when external redundancy was reduced, the normal CAS could still process the stimulus with a high degree of intelligibility. When there was a central auditory lesion, however, central processing appeared to become over-taxed by the more complex material, and as a result, there was a breakdown in intelligibility. This phenomenon led Jerger (1960) to propose that central auditory processing was characterized by a "subtlety principle" whereby more complex (subtle) stimuli were necessary to detect higher central auditory lesions than were required to locate lesions at lower levels.

The majority of central auditory tests developed to date have employed some form of distortion to reduce external speech redundancy. Such stimuli have included filtered speech (Jerger, 1960, 1964; Matzker, 1962; Speaks and Jerger, 1965), periodically switched speech (Bocca and Calearo, 1963; Calearo and DiMitri, 1958; Calearo, Teatini, and Pestalozza, 1962), and interrupted speech (Bocca and Calearo, 1963). In addition, it has been shown that temporal parameters play a major role in speech perception (Aaronson, 1967; Beasley and Shriner, 1971; Hirsh, 1967). Thus, temporally altered speech in the form of time compression has been suggested as a unique means to assess central auditory problems.

Calearo and Lazzaroni (1957) examined the effects of presentation level and syllable rate on the intelligibility of a list of short significant sentences presented to normal and presbycusic subjects. Sentences were recorded at rates

of 140, 250, and 350 words per minute (wpm) and articulation functions obtained on each group of subjects. Results indicated that articulation functions for the normal group were shifted by 5 to 10 dB when sentences were accelerated from 140 wpm to 250 wpm and 10 to 15 dB when presented at 350 wpm. For presbycusic subjects, a 30 dB shift was observed at 250 wpm and thresholds could not be established at maximum intensity levels when sentences were presented at 350 wpm. The three articulation functions for normal subjects remained essentially parallel, indicating that loss of intelligibility associated with speech acceleration could be restored by an increase in intensity. Calearo and Lazzaroni also reported that when accelerated sentences were presented to a group of subjects with temporal lobe damage, articulation scores were poorer in the ear contralateral to the lesion when compared to the homolateral ear.

The findings of this investigation are difficult to interpret because Calearo and Lazzaroni failed to describe the exact nature of their speech stimuli, qualify their subject samples, or provide a description of the methodology used to time-compress speech materials. Nevertheless, two general conclusions may be drawn from their results. First, presbycusic individuals had a special difficulty processing time-compressed speech stimuli; and secondly, cortical damage resulted in poorer discrimination ability when stimuli were presented to the ear contralateral to the site-of-lesion.

deQuiros (1964) conducted an investigation similar to that of Calearo and Lazzaroni. deQuiros presented an accelerated speech task to twenty normal hearing persons, fifteen subjects with peripheral hearing loss (5 conductive and 10 cochlear), seven subjects labelled as presbycusic, six persons with retrocochlear lesions, and twenty-eight subjects with central auditory pathology. Speech stimuli consisted of sentences (ten words in length) presented to subjects at rates of 140, 250, and 350 wpm. Apparently, speech stimuli were presented to each subject via a monitored live voice technique. Resultant data were examined with respect to the shape of articulation functions, speech detection and reception thresholds, and maximum articulation scores. deQuiros noted that normal hearing subjects usually demonstrated a common articulation curve for each presentation rate. An approximate 10 dB shift was observed for successive word rates, with the exception of detection thresholds, which tended to remain constant. Subjects with conductive hearing loss either obtained results similar to normals, or the entire family of curves was shifted by an amount consistent with the degree of conductive involvement. Cochlear impaired subjects occasionally obtained normal results, but more frequently, the maximum score at 350 wpm was lower than that obtained for normal subjects. Results for presbycusics were similar to those reported by Calearo and Lazzaroni. Unlike the other subject groups, however, presbycusics showed a shift in the threshold of detectability for all presentation rates. For subjects with central auditory pathology, it was

found that a bilateral shift in threshold occurred when intercranial pressure resulted from an extratemporal tumor. A bilateral threshold shift was also observed when intercranial pressure was due to a temporal lobe tumor, but was more severe in the ear contralateral to the lesion. For extratemporal tumors without changes in intercranial pressure, the threshold shift was small and symmetrical. Based on these findings, deQuiros concluded that accelerated speech testing may provide information that "... when correlated with other findings - may aid in pinpointing the sites of brain lesions, especially those within the temporal lobe" (p. 40).

The findings reported by Calearo and Lazzaroni and by deQuiros resulted in several investigations designed to study the responses of aged subjects to time-compressed speech. Luterman, Welsh, and Melrose (1966) found that time-compressing and expanding monosyllabic words (CID W-22's) (Hirsh et al., 1952) by 10% and 20% of normal duration had a slight effect on overall intelligibility, but there were no significant differences between the performance of young normal hearing subjects, young sensorineurally impaired persons, and aged subjects with sensorineural hearing loss. Conversely, Sticht and Gray (1969) noted that time-compression had a differential effect upon the perceptual performance of young and aged persons. They observed that when CID W-22 words were presented at compression levels of 36, 46, and 59% to young and aged listeners matched for hearing sensiti-

vity, younger listeners performed better than aged persons and that the difference in performance became greater as the amount of time compression was increased. In addition, they reported that while aged subjects experienced difficulty with time-compressed speech, there were no differential effects on performance due to hearing loss. Sticht and Gray concluded that the detrimental effects of time compression on the speech discrimination scores of aging individuals reflected changes within the central rather than peripheral auditory system.

Schon (1970) presented 25-word CID W-22 lists that were compressed by 30% and 50% to groups of young subjects with normal hearing, aged subjects with normal hearing for their age, young subjects with sensorineural hearing loss, aged subjects with sensorineural loss, and young subjects with normal hearing up to 3000 Hz, but a hearing loss of 40 dB at 4000 Hz. In general, Schon's findings supported Sticht and Gray in that aged individuals experienced difficulty in the discrimination of time compressed speech. Unlike Sticht and Gray, however, Schon stated that both peripheral and central auditory factors contributed to the decreased performance of aged persons. DiCarlo and Taub (1972) measured the word intelligibility of twenty young and twenty aged aphasic subjects on the same word lists (25-word CID W-22's) under the same time compression ratios (30% and 50%) employed by Schon. Their results indicated that temporally accelerated speech stimuli were effective in distinguishing between central (i.e., aphasic subjects) and peripheral auditory problems, but were less effective in differentiating lesions related to the peripheral auditory mechanism.

Although the findings concerned with the intelligibility of time compressed speech and aging populations has been equivocal, the afore-going research has illustrated that temporally accelerated speech provides a unique stimuli for central auditory testing. It is important to note, however, that results from this series of investigations did not provide adequate data for clinical diagnostic purposes. For example, investigators either failed to use suitable time compression procedures (Calearo and Lazzaroni, 1957; deQuiros, 1964), neglected to match subject groups for perceptual ability under normal listening conditions (i.e., undistorted speech) (Schon, 1970; DiCarlo and Taub, 1972), or used small subject samples (Sticht and Gray, 1969). Moreover, the half-list revisions of the CID W-22 word lists (Campbell, 1965) used by Schon and DiCarlo and Taub have not received standardization for reliability and equivalency for time compressed conditions. In order to obtain a clinically useful test, procedures for time-compression must be well defined and standardized test materials should be used as stimuli.

Since the CID W-22 speech discrimination test had been criticized as being too easy (Carhart, 1965), several investigators have examined the effects of time compression on the NU-6 test of speech discrimination. Beasley, Schwimmer, and Rintelmann (1972b) obtained intelligibility scores for ninety-six normal hearing young adults on Form B of the NU-6. They

presented stimuli at six time compression ratios (0, 30, 40, 50, 60, and 70%) and at four sensation levels (8, 16, 24, and 32 dB) to an equal number of right and left ears. Results indicated that discrimination performance decreased gradually until the 70% time compression condition, at which point a precipitous drop in intelligibility was noted. As sensation level was increased intelligibility scores also increased and there were no significant differences in performance between ears. Beasley, Forman, and Rintelmann (1972a) expanded the data of Beasley et al. (1972b) to a 40 dB sensation level and found a slight, non-significant improvement in discrimination scores. Beasley et al. (1972a) concluded that since "... normative speech discrimination data is available at five intensity levels for six time compression conditions, it is now possible to compare meaningfully the performance of patients with auditory pathology to normal Ss" (p. 74).

Kurdziel and Noffsinger (1973) used the normative data of Beasley et al. (1972a,b) to investigate the performance of adults with cortical (temporal lobe) brain damage. They reported scores for NU-6 stimuli time-compressed by 60% to be significantly poorer in the ear contralateral to the brain damage as compared to scores for the ipsilateral ear. These findings lend support to the observations of Calearo and Lazzaroni (1957) and deQuiros (1964) who also noted scores to be poorer in the ear contralateral to cortical damage.

In an attempt to resolve the equivocal results reported for time compressed speech in aging populations, Konkle, Beasley, and Bess (1975) administered time compressed NU-6 lists to 118 aging subjects. Their subjects, who had excellent discrimination ability for NU-6 words under normal conditions (i.e., 0% time-compression), were divided into four age groups (54-60 years, 61-67 years, 68-74 years, and 75 years of age and older). Experimental stimuli were presented at 0, 20, 40, and 60% time-compression and at sensation levels of 24, 32, and 40 dB to an equal number of right and left ears and male and female subjects. Konkle et al. found that intelligibility scores became poorer as a function of increased age and time compression ratio, but that increased sensation level caused scores to improve. Since their subjects demonstrated normal discrimination ability at 0% time-compression, Konkle et al. argued that differences in performance between the four aging groups could not be attributed to peripheral auditory function. Consequently, Konkle et al. concluded that the differential performance may be due to changes within the central auditory system associated with the aging process.

Only one investigation has been reported that was designed to examine the effects of time compressed NU-6 lists on the discrimination ability of individuals with peripheral auditory lesion. Kurdziel, Rintelmann, and Beasley (1975) presented NU-6 monosyllables at six levels of time compression (0, 30, 40, 50, 60, and 70%) under four sensation levels (16, 24, 32, and 40 dB) to a group of nine subjects with bilateral noise-induced hearing impairments. Results indi-

cated that the effects of time compression on discrimination ability were similar to those reported for normal hearing subjects by Beasley et al. (1972a,b). That is, performance gradually decreased with increased time-compression up to 60% acceleration, and a dramatic breakdown in scores occurred at 70% time-compression. Maximum discrimination performance was obtained at the 32 dB sensation level and a slight roll-over phenomenon was observed when stimuli were presented at the highest sensation level (40 dB). This latter finding stressed the importance of presenting stimuli at several intensity levels in order to determine maximum performance.

The review of literature concerned with time compressed speech as a test of central auditory function has revealed that accelerated speech stimuli may be useful in delineating problems in the CAS from those confined to the peripheral auditory mechanisms. More specifically, it appears that sufficient data exists for time compressed versions of the NU-6 to receive serious consideration as a clinical diagnostic tool.

It is important to note, however, that every investigation reported to date has presented time compressed NU-6 word lists monaurally under earphones. Numerous investigators (Konig, 1962a,b; Naunton, 1960; Palva, 1954, 1958, 1962; Zwislocki, 1951, 1953) have demonstrated that an auditory signal presented to one ear may be perceived in the other ear whenever the level of presentation exceeds interaural attenuation. This phenomenon has been commonly termed "cross hearing". For air conducted speech stimuli presented via earphones the minimal interaural attenuation has been found to be approximately 40 dB. Since stimuli presented to one ear by an earphone is transduced to the opposite cochlea primarily by bone conduction, Studebaker (1967) has recommended that the non-test ear be masked whenever the presentation level in the test ear exceeds bone conduction sensitivity of the non-test ear by 40 dB. Contralateral masking (i.e., masking the non-test ear) was not used in any of the investigations employing time-compressed NU-6 stimuli. Hence, it is possible that the results from these investigations may have reflected non-test ear participation.

Contralateral Masking and Speech Intelligibility

The primary purpose of contralateral masking has been to elevate the threshold sensitivity in the non-test ear to avoid the influence of "cross hearing" on responses obtained from the test ear. Research has shown, however, that contralateral masking may also affect the responses from the test ear.

The majority of research in this area has been concentrated on the effect of a contralateral masker on various measures of pure tone threshold. Numerous investigators (Dirks, 1964; Dirks and Malmquist, 1965; Dirks and Norris, 1966; Ingham, 1959; Sherrick and Mangabeira-Albernaz, 1961; Treisman, 1963; Wegel and Lane, 1924; Zwislocki, 1953;

Zwislocki, Damianopoulous, Buining, and Glantz, 1967; Zwislocki, Buining, and Glantz, 1968) have reported changes in the pure tone threshold sensitivity of the test ear when low-intensity masking was delivered to the non-test ear. This effect has been generally referred to as "central masking" and attributed to central rather than peripheral auditory processes.

Conversely, a paucity of information has been published directly concerned with the effect of contralateral noise on speech audiometric results. Martin, Bailey, and Pappas (1965) observed that speech reception thresholds measured via a Bekesy tracking procedure shifted 5 to 8 dB when white noise was administered to the non-test ear at a sensation level of 75 dB. In a follow-up study, Martin (1966) examined the effect of a white noise contralateral masker on speech reception thresholds determined by CID W-1 spondee words and on discrimination scores obtained with PB word lists. Results of this investigation indicated a shift in speech reception thresholds of approximately 5 dB with essentially no change in discrimination scores, except in cases where "cross hearing" could be expected.

More recently, Young and Harbert (1970) obtained discrimination scores with CID W-22's in the presence of ipsilateral and contralateral white noise maskers in seven normal hearing subjects, sixty-five subjects with total hearing loss in one ear and normal hearing in the opposite ear, and fifteen subjects with bilateral symmetrical hearing loss. Their

results indicated that contralateral masking had little effect on discrimination scores until intensity levels were reached that caused the masker to cross to the test ear, thereby reducing the S/N ratio in the test ear and resulting in depressed discrimination scores.

Jerger and Jerger (1975) measured performance on synthetic sentence identification materials administered in the presence of a competing message (i.e., a spoken passage) to sixteen patients with intra-axial brain stem lesions. Performance was measured in various stimuli-to-competition ratios from 0 to -40 dB. Jerger and Jerger reported that performance generally remained within the range observed for normal subjects.

The findings from the investigations of Martin (1966), Young and Harbert (1970), and Jerger and Jerger (1975) suggest that contralateral masking has little effect on speech discrimination scores. Spencer and Priede (1974), however, provided data that indicated a small percentage of normal hearing individuals could be expected to show a 1% decrease in intelligibility for every 3 dB increase in sensation level of a wide-band noise contralateral masker. They concluded that this finding was caused by central masking phenomenon.

Currently, there is no literature directly concerned with the effects of contralateral masking on time compressed speech discrimination tests. Since these tasks have been shown to be sensitive to central auditory lesions, it is

possible that the central component associated with contralateral masking may interact with time compressed speech stimuli. For example, Beasley et al. (1972b) did not observe a difference in performance between right and left ears when listeners were presented time compressed NU-6 words. Based on these findings they suggested "... that time-compressed speech can be clinically utilized in a monotic listening task without being confounded by ear laterality effects" (p. 348). Previous research with dichotic listening tasks employing speech stimuli, however, have demonstrated a right ear advantage even when listeners were instructed to report only right or left ear stimuli (Berlin, 1972; Kimura, 1967). Masking the non-test ear while time compressed stimuli are simultaneously presented to the test ear creates a dichotic listening condition. It appears possible, therefore, that contralateral masking may result in a perceptual difference between ears. Furthermore, such laterality effects may be enhanced as time compression ratio increases and external redundancy is reduced. If this were the case, existing normative data for time compressed versions of the NU-6 test may confound diagnostic results pertinent to identification of central auditory lesion.

With the exception of Jerger and Jerger (1975), each investigation involving the exploration of contralateral masking on speech intelligibility used a white noise masking stimulus. Research with ipsilateral maskers (i.e., masking the test ear) has revealed that spectral and temporal

parameters of the masker may have a direct bearing upon masker effectiveness. Miller (1947) reported "... the masking of speech to depend on three characteristics of the masking sound: (1) its intensity relative to the intensity of the speech, (2) its acoustic spectrum, and (3) its temporal continuity" (p. 106). Hawkins and Stevens (1950) compared the masking curves for the threshold of speech intelligibility to the masking functions for pure tones obtained monaurally with a white noise masker. They found the masking function for speech most closely paralleled the average threshold functions for 500, 1000, and 2000 Hz. These results indicated that the most efficient maskers for speech were stimuli characterized by a spectrum with energy in the lower third of the range from 100 to 6000 Hz.

Regarding temporal parameters, Carhart and his associates (Carhart, Tillman, and Johnson, 1966; Carhart, Tillman, and Greetis, 1969; Carhart, Nicholls, and Kacena, 1972) have conducted several investigations dealing with the effects on spondee thresholds of maskers composed of speech combined with white noise or with other speech signals. Results of these investigations revealed that when white noise was combined with speech there was approximately 3 dB more masking than could be predicted from simple summation of the average intensities of the two maskers. Moreover, when speech was combined with another speech signal, approximately 7 dB more masking was observed than could be attributed to simple addition. This phenomenon has been termed perceptual

masking and is felt to be caused when competing signals are semantically meaningful as compared to masker noise that lacks meaning, e.g., white noise. Carhart et al. (1972) noted that perceptual masking increased up to the combination of four speech signals. Maskers that contained more than four speech signals did not cause a substantial increase in perceptual masking as compared to the four signal maskers.

Presently, the relationship between white noise, filtered white noise (i.e., speech noise), or multitalker complexes used as contralateral maskers has not been examined. Consequently, any interaction of these stimuli when presented in a contralateral paradigm with accelerated speech, such as the time compressed versions of the NU-6, is unknown.

Summary and Statement of the Problem

The afore-going review of the literature has shown that accelerated speech provides a unique stimuli to distinguish central from peripheral auditory problems. The NU-6 test of auditory speech discrimination has been time-compressed using controlled methods, and data has been reported for young and aging persons with normal hearing, as well as persons with temporal lobe damage. The effects of contralateral masking on the perception of time compressed speech, however, is unknown.

Contralateral masking is a well recognized audiometric procedure commonly employed in clinical situations with suprathreshold speech discrimination tasks. Since the two

most common clinical maskers of speech stimuli are white noise and speech noise, the effects of these two stimuli as contralateral maskers of accelerated speech need to be determined before time compressed NU-6 word lists may be routinely used in clinical settings. In addition, because multitalker maskers have been shown to cause perceptual masking when presented ipsilaterally, it appears desirable to ascertain the effect of this type masker in a contralateral condition. For example, it may be possible that perceptual masking is a time-based process; or at least dependent upon temporal parameters. Such information may help to elucidate the perceptual process whereby a listener is able to selectively attend to one stimulus in the presence of a competing signal.

It was the purpose of this investigation, therefore, to examine the relationship between contralateral masking and the perception of time compressed NU-6 speech discrimination lists. Specifically, the following questions were investigated:

1. Will white noise (WN), speech noise (SN), multitalker (MT), or multitalker 60% time-compressed (MT60%) stimuli presented as contralateral maskers have similar effects on speech intelligibility measured by the NU-6 presented to the ipsilateral ear?
2. Will the intensity level of WN, SN, MT, or MT60% stimuli presented as contralateral maskers have

similar effects on speech intelligibility measured by the NU-6 presented to the ipsilateral ear?

3. Will WN, SN, MT, or MT60% stimuli presented as contralateral maskers have similar effects on speech intelligibility measured by time compressed versions of the NU-6 presented to the ipsilateral ear?
4. Will WN, SN, MT, MT60% stimuli presented as contralateral maskers to the right ear have a similar effect on speech intelligibility of NU-6 stimuli presented to the left ear, as when the contralateral maskers are presented to the left ear and NU-6 stimuli presented to the right ear?

CHAPTER II

EXPERIMENTAL METHODS

This investigation was designed to examine the effects of contralateral masking on a test of central auditory function. The NU-6 test of speech discrimination (time-compressed by 0%, 30%, and 60%) was presented to ninety normal hearing young adult listeners under four conditions of contralateral masking (WN, SN, MT, and MT60%). Behavioral responses for each condition were obtained for an equal number of right and left test ears. The experimental design used in the investigation is shown in Figure 3, on page 25.

Subjects

Ninety normal hearing young adults were selected from a university population to serve as subjects. This sample consisted of 22 males and 68 females. Subjects ranged in age from 19 years to 26 years with a mean age of 23.2 years. In order to qualify for the investigation, each subject met the following criteria: 1) pure tone air conduction thresholds in each ear of 15 dB HTL (re: ANSI, 1969) or better for the octaves 250 through 4000 Hz, plus the half-octave of 6000 Hz, 2) bone conduction pure tone thresholds within ±10 dB of air conduction thresholds, except for 6000 Hz where bone conduction responses were not obtained, and 3) speech reception thresholds of 15 dB HTL (re: ANSI, 1969) or better bilaterally. Potential subjects who did not meet these criteria were not included in the investigation.

Stimuli

Speech reception thresholds were measured with tape recorded versions of the CID W-1 word lists described previously by Rintelmann et al. (1974). The four lists comprising Form B of the NU-6 were used as time compressed stimuli (0%, 30% and 60%) and consisted of the tape recorded materials used by Beasley et al. (1972a,b).

The source for white and speech noise maskers was a two-channel speech audiometer (Grason-Stadler, Model 162). The frequency spectra for these maskers when transduced by a TDH 39-10Z earphone are presented in Figure 1. The white noise masker had a flat frequency spectrum within ± 1 dB from 100 to 4000 Hz. The speech noise masker was characterized by a 3 dB per octave drop from 250 to 1000 Hz and a 6 dB per octave drop from 1000 to 4000 Hz.

Four male talkers simultaneously reading a passage about the general scope of psychology (James, 1973) comprised the multitalker maskers. In order to generate these maskers, each talker individually read the passage at normal conversational speech and effort level into a microphone (Electrovoice, Model 635A) located in an audiometric test room (IAC, Series

400). The microphone was connected through the wall of the test room to a four channel tape recorder (Ampex, Model AG 440B, frequency response = 50 to 15000 Hz $\pm$2 dB per channel). Each passage was recorded on a single track of a four track magnetic tape. This tape was then re-recorded from the same tape recorder, with each track fed to a four channel microphone mixer (Shure, Model M67) connected to the input on an electrical time-compressor/expander (Lexicon, Model Varispeech I, frequency response = 50 to 15000 Hz $\pm$3 dB) where each talker passage was simultaneously recorded on the same track of a master tape. The master tape was then processed following the method recommended by Konkle et al. (1975) through the Lexicon time-compressor/expander at 0% and 60% time-compression, and experimental tapes recorded on the Ampex Model AG 440B tape recorder that was connected to the time-compressor/expander. The Varispeech I was calibrated to manufacturers specifications before tape recordings were made.

The frequency spectra of the multitalker maskers may also be seen in Figure 1. Frequency spectra of both multitalker maskers approximated the configuration of the speech noise maskers, particularly when the multitalker masker was time-compressed by 60%. Both multitalker maskers, however, contained less low frequency energy (below 100 Hz) and high frequency energy (above 1200 Hz) than the speech noise. When the multitalker masker was at normal duration the major area of energy concentration was at 500 Hz, whereas, for the

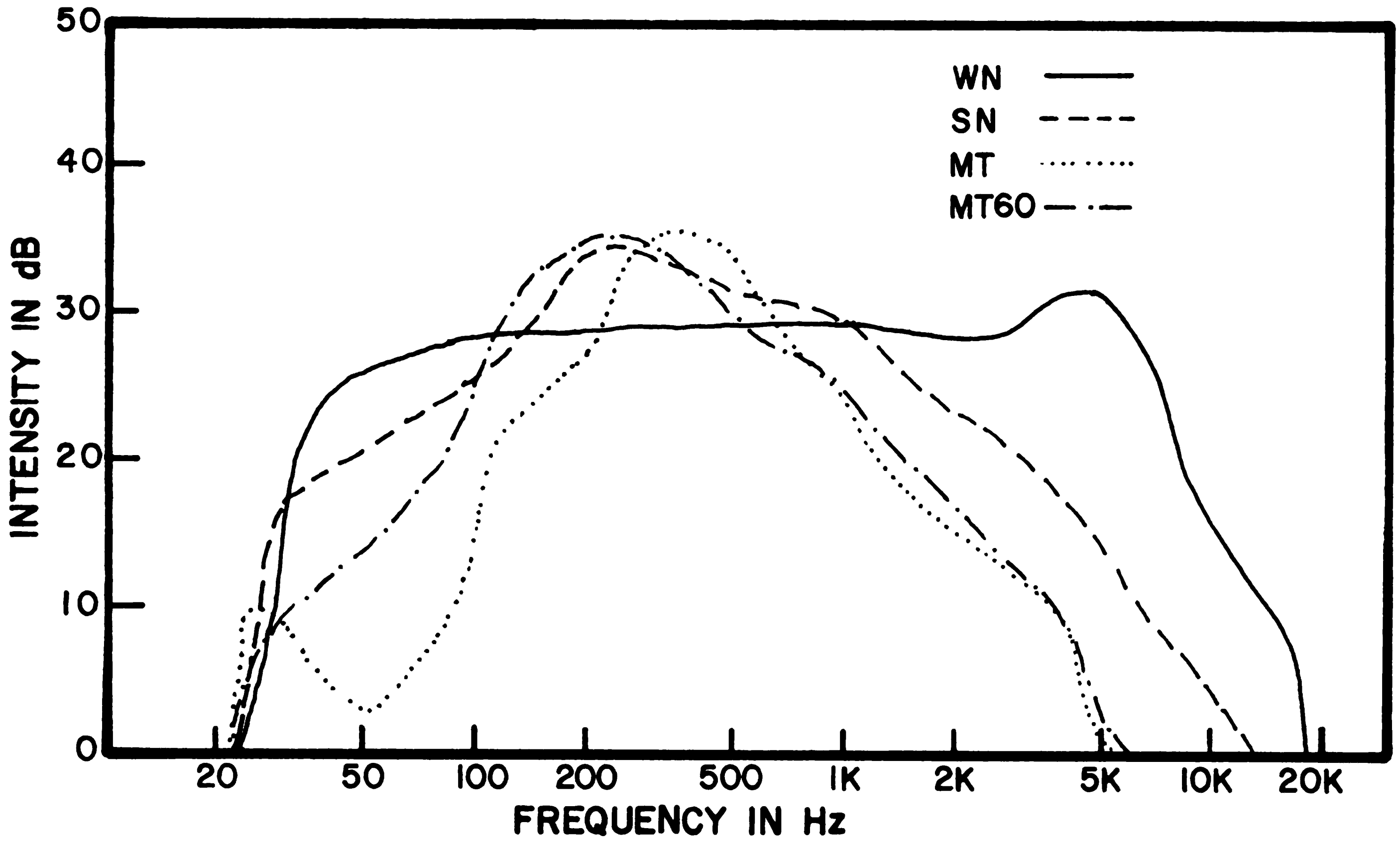

Figure 1. Frequency spectra of four maskers (WN = white noise, SN = speech noise, MT = multitalker, and MT60 = multitalker 60% time-compressed) used as contralateral masking stimuli.

speech noise and 60% time-compressed multitalker maskers the major energy concentration centered at 250 Hz. The method and procedures used to obtain the frequency spectra of all four maskers may be found in Appendix A.

Apparatus

All subjects were tested in an IAC 1200 series double walled test chamber. Located in the control room of the test suite were a two channel tape recorder (Ampex, Model AG 600-2, frequency response - 50 to 15000 Hz $\pm$2 dB) and a clinical audiometer (Beltone, Model 15C). The tape recorder fed speech and multitalker masking stimuli to a two channel speech audiometer (Grason-Stadler, Model 162). Signals from the audiometers were transduced via TDH 39-10Z earphones mounted in MX 41/AR cushions located in the attached listening room. Bone conducted pure tone stimuli were delivered by a Radioear B70A white dot vibrator. A talk-back system, comprised of a microphone (Shure, Model 560) located in the listening room and connected through the speech audiometer to TDH 39-10Z earphones and associated MX 41/AR cushions, allowed the examiner to monitor verbal responses. A schematic representation of the apparatus is shown in Figure 2.

The ambient noise level in the listening room of the sound suite was measured at 44 dB SPL (re: 0.0002 dyne/cm^2) on the C scale of a sound level meter (Bruel and Kjaer, type 4145). This noise level was sufficiently low as not to interfere with the listening tasks. Prior to experimental

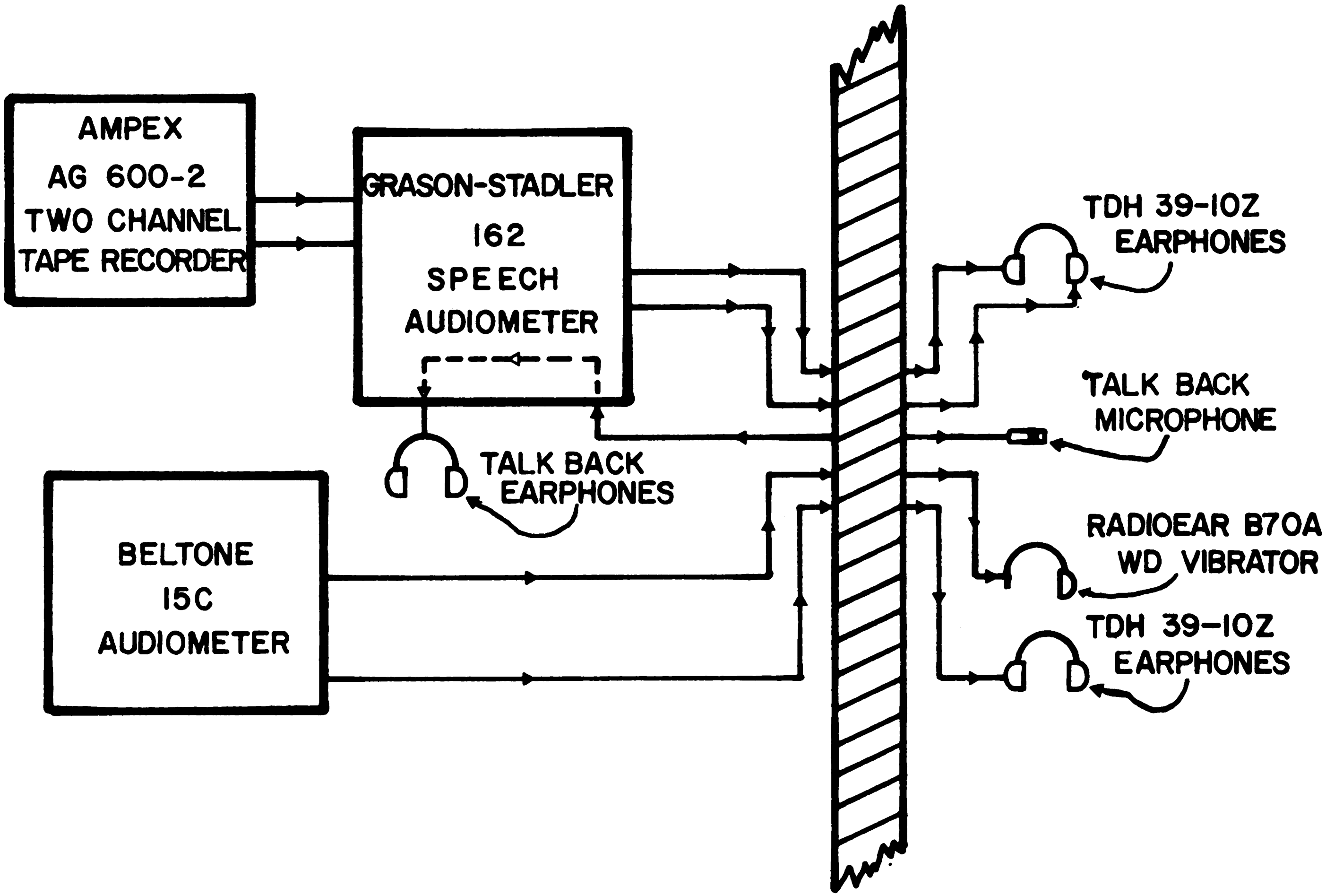

Figure 2. Schematic of apparatus used to present experimental stimuli.

testing, the apparatus was calibrated to ANSI (S3.6-1969) specifications and periodic calibration checks made throughout the investigation revealed that the apparatus remained stable (i.e., met ANSI specifications) through the duration of testing.

Procedures

Pure tone air and bone conduction thresholds were initially established for each subject by the modified Hughson-Westlake technique (Carhart and Jerger, 1959) and the procedure suggested by Tillman and Carhart (1966) was used to measure speech reception thresholds. Each subject was then randomly assigned to one of the nine time-compression/masker intensity conditions so that there were ten listeners for each combination of time compression and masker intensity level. Within each group of ten listeners, however, there were an equal number of right and left test ears. The total breakdown of subjects into experimental conditions may be seen in Figure 3.

Following the determination of pure tone and speech reception thresholds, standardized instructions (see Appendix B) were given to each subject in written form and also read orally by the examiner. Time compressed NU-6 word lists were administered at the single intensity level of 75 dB SPL (re: 0.0002 dyne/cm^2). Contralateral maskers were presented at intensity levels of either 30, 60, or 90 dB SPL (re: 0.0002 dyne/cm^2) depending upon the experimental

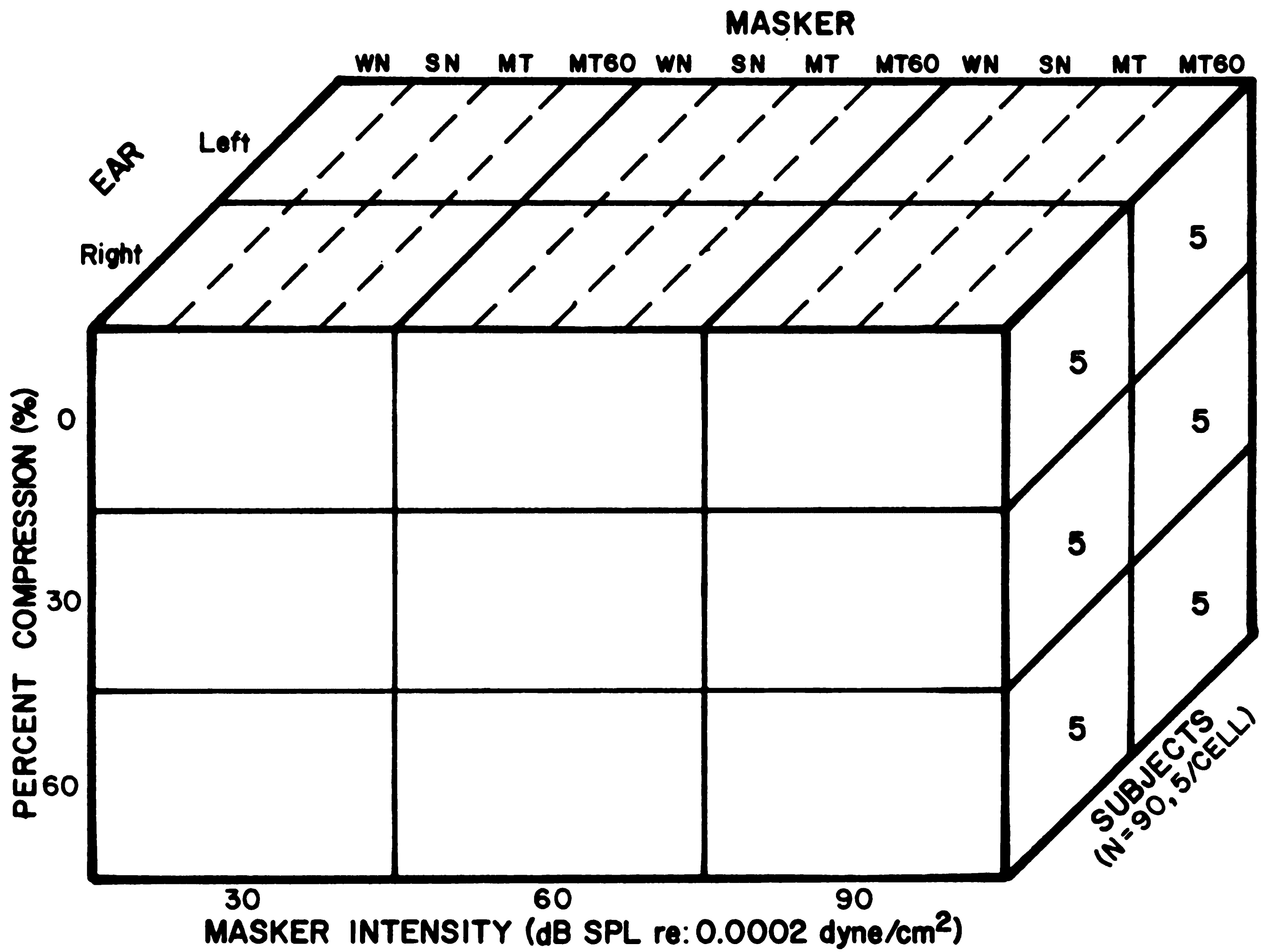

Figure 3. Experimental design.

condition. Regardless of test ear, the time compressed stimuli were always presented via the right earphone with the masker stimuli presented from the left earphone.

Subjects were tested individually in a manner that allowed the four lists of NU-6 Form B to be administered to the test ear at a single time compression ratio. At the same time, each list competed with one of the four maskers presented to the non-test ear at the same intensity level. The word lists and presentation order of the four masker types was counterbalanced across experimental conditions. Finally, a standardized answer form (see Appendix C) was provided prior to the administration of each list for subjects to record their responses.

Analysis

Subjects' responses on each NU-6 list were tabulated and changed to percent correct scores. A multiple linear regression analysis (Nie, Bent, and Hull, 1970) was performed with the dependent variable (percent correct score) projected on the independent variables (time-compression, masker intensity level, masker type, and ear) with masker type coded as a dummy variable. Two equations were developed (see Appendix D) to determine the amount of the total variance (i.e., predictability) of the dependent variable that was attributed to the independent variables. The equations were submitted to a stepwise computer analysis (Michigan State University, SPSS - Regression, version 6.0)

that yielded Pearson rs, multiple correlations (Rs), R-squared, and standardized Beta weights. The percent correct scores obtained by each subject in the various experimental conditions are shown in Appendix E.

CHAPTER III

RESULTS

The results of the stepwise multiple linear regression analysis indicated that neither white noise nor speech noise had a significant effect on the intelligibility of time compressed NU-6 word lists. Conversely, the multitalker maskers were found to react with other variables (i.e., time-compression, masker intensity level, and ear) in a manner that caused a statistically significant alteration in speech intelligibility.

The zero-order correlation coefficients for percent correct score with each variable and variable combination entered into equations I and II are shown in Table 1. Fifteen of the possible thirty-four correlations were statistically significant ($p > 0.05$). Moreover, all of the significant correlations were negative, thereby demonstrating that increasing masker and time compression values were associated with decreasing discrimination performance. Eleven of the fifteen significant correlations were comprised of either the MT or MT60% maskers combined with other variables. These findings suggested that white noise and speech noise presented as contralateral maskers had a negligible effect

Table 1. --Zero-Order Correlations for Percent Correct Score Regressed on Independent Variables.

Variable	r	Variable	r	Variable	r	Variable	r
X_2	-0.23*	X_{35}	-0.07	X_{347}	-0.17*	X_{236}	-0.08
X_3	-0.54*	X_{45}	0.05	X_{2347}	-0.22*	X_{346}	-0.02
X_4	0.04	X_{234}	-0.09	X_{24}	-0.04	X_{2346}	-0.04
X_5	0.11	X_{2345}	-0.06	X_{234}	-0.31*	X_{28}	-0.11*
X_6	0.08	X_{345}	-0.05	X_{26}	0.05	X_{38}	-0.26*
X_7	-0.14*	X_{27}	-0.20*	X_{36}	-0.07	X_{48}	-0.03
X_8	-0.04	X_{37}	-0.34*	X_{46}	0.09	X_{238}	-0.32*
X_{23}	-0.59*	X_{47}	-0.04	X_{2348}	-0.24*	X_{348}	-0.19*
X_{25}	0.07	X_{237}	-0.39*				

* = $p > 0.05$

X_2 = Masker Level X_5 = WN X_8 = MT60%

X_3 = Time-compression X_6 = SN X_{23} to X_{2348} = Variable Combinations

X_4 = Ear X_7 = MT

on the intelligibility of time compressed NU-6 stimuli.

A more definitive description of the relationship between discrimination performance measured by time compressed NU-6 words and contralateral masking were found from the regression equations yielded by the stepwise computer analysis. Table 2 presents the analysis of variance, coefficients of multiple correlation (R), and coefficients of determination (R^2) for equations I and II extended through the seventh-order stages improved Rs by only 0.00352 for equation I and 0.00313 for equation II, only the first eight stages (i.e., zero-order through seventh-order) are reported for each equation. The significant F values indicated that differences existed between the various MrL, TC, Ear, and masker type (MrT) experimental conditions. In addition, the R^2 values suggested that the percent correct scores obtained by subjects were not completely accounted for by the independent variables. This was not surprising since the purpose of this investigation was to examine the effect of only selected variables (MrL, TC, Ear, and MT), with other important variables such as hearing sensitivity and age held constant. The R^2 values indicated that 43.7% of the total variance for discrimination scores was accounted for by the seventh-order equations as compared to 44.8% for total equations.

White Noise and Speech Noise as Contralateral Maskers

The seventh-order stepwise computer analysis allowed

Table 2. --Analysis of Variance, Multiple R, and R-squared values for Percent Correct Score Regressed on Independent Variables for Equations I and II through Step Eight.

	Equation I		Equation II	
Source of Variance	Regression	Residual	Regression	Residual
Sum of Squares	3098.05	3979.27	3098.05	3979.27
Degrees of Freedom	8	351	8	351
Mean of Squares	387.25	11.34	440.48	11.34
F Value		34.16*		34.16*
Multiple R		0.66162		0.66162
R Squared		0.43774		0.43774

* = $p > 0.05$

for eight variables to enter each equation. For each equation, these variables were identical and entered equations in the same order. Tables 3 and 4 present the standardized Beta weights (B) and the F values associated with each variable as a function of successive stages (i.e., step 1 through step 8).

Examination of Tables 3 and 4 reveals that white noise and speech noise contralateral maskers lacked sufficient impact on percent correct scores to be included in the seventh-order multiple regression equations. In fact, the WN masker did not enter equation I until the fifteenth stage and only caused an R change of 0.00059. Similarly, the SN masker did not enter equation II until the eleventh stage with an R change of 0.00065. These values were not statistically significant ($p > 0.05$).

Graphic illustrations of these findings may be seen in Figures 4 through 8. The greatest differences between conditions for these two maskers occurred when SN was presented to the contralateral ear at an intensity level of 90 dB SPL and the NU-6 words were time-compressed by 30% (see Figure 5). This difference, however, was only 2.2% (see Appendix F). When data obtained in this investigation were compared to the findings of Beasley et al. (1972a) for the same time compressed NU-6 stimuli without contralateral masking (see Figures 4 to 6), it became readily apparent that contralateral masking with WN or SN stimuli had essentially no effect on the intelligibility of NU-6 words regardless

Table 3. --Zero-Order through Seventh-Order Standardized Beta Weights (B) and F Values of Percent Correct Score Regressed on Independent Variables for Equation I.

Step		Variables							
		X_{23}	X_{37}	X_{238}	X_{347}	X_{2347}	X_3	X_2	X_8
1.	B	-0.59							
	F	188.47*							
2.	B	-0.53	-0.19						
	F	148.87*	20.04*						
3.	B	-0.44	-0.25	-0.20					
	F	88.86*	32.60*	20.15*					
4.	B	-0.44	-0.33	-0.20	0.11				
	F	89.63*	32.29*	20.32*	4.06*				
5.	B	-0.42	-0.33	-0.21	0.29	-0.19			
	F	78.36*	33.77*	21.92*	6.86*	3.48			
6.	B	-0.30	-0.32	-0.20	0.34	0.25	-0.14		
	F	14.20*	30.29*	21.20*	8.99*	5.33*	3.14		

Table 3. --Continued

Step		X_{23}	X_{37}	X_{238}	X_{347}	X_{2347}	X_3	X_2	X_8
		Variables							
7.	B	-0.14	-0.32	-0.20	0.34	-0.25	-0.28	-0.11	
	F	1.34	30.46*	21.24*	9.02*	5.36*	6.50*	3.34	
8.	B	-0.12	-0.32	-0.26	0.35	-0.26	-0.28	-0.11	0.06
	F	0.95	29.90*	16.83*	9.48*	5.76*	6.62*	3.33	1.29

* = $p > 0.05$

X_{23} = Masker Level X Time-compression

X_{37} = Time-compression X MT

X_{238} = Masker Level X Time-compression X MT60%

X_{347} = Time-compression X Ear X MT

X_{2347} = Masker Level X Time-compression X Ear X MT

X_3 = Time-compression

X_2 = Masker Level

X_8 = MT60%

Table 4. --Zero-Order through Seventh-Order Standardized Beta Weights (B) for F Values of Percent Correct Score Regressed on Independent Variables for Equation II.

		Variables						
Step		X_{23}	X_{37}	X_{238}	X_{347}	X_{2347}	X_3	X_2	X_8
1.	B	-0.59							
	F	188.48*							
2.	B	-0.53	-0.19						
	F	148.87*	20.04*						
3.	B	-0.44	-0.25	-0.20					
	F	88.87*	32.60*	20.15*					
4.	B	-0.44	-0.33	-0.20	0.11				
	F	89.63*	32.29*	20.32*	4.06*				
5.	B	-0.42	-0.33	-0.21	0.29	-0.20			
	F	78.36*	33.77*	21.92*	6.86*	3.48			
6.	B	-0.30	-0.32	-0.21	0.34	-0.24	-0.14		
	F	14.20*	30.29*	21.20*	8.99*	5.33*	3.14		

Table 4. --Continued

		Variables							
Step		X_{23}	X_{37}	X_{238}	X_{347}	X_{2347}	X_3	X_2	X_8
7.	B	-0.14	-0.32	-0.21	0.34	-0.25	-0.28	-0.11	
	F	1.34	30.46*	21.24*	9.06*	5.36*	6.50*	3.34	
8.	B	-0.12	-0.32	-0.26	0.35	-0.26	-0.28	-0.11	0.06
	F	0.96	29.91*	16.83*	9.48*	5.76*	6.62*	3.33	1.29

* = $p > 0.05$

X_{23} = Masker Level X Time-compression

X_{37} = Time-compression X MT

X_{238} = Masker Level X Time-compression X MT60%

X_{347} = Time-compression X Ear X MT

X_{2347} = Masker Level X Time-compression X Ear X MT

X_3 = Time-compression

X_2 = Masker Level

X_8 = MT60%

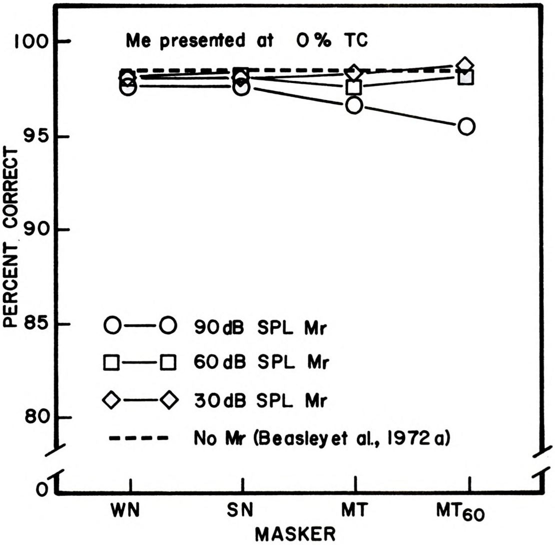

Figure 4. Mean percent correct scores for 0% time-compression as a function of masker type and intensity. The Beasley et al. (1972a) data without contralateral masking are shown for comparison.

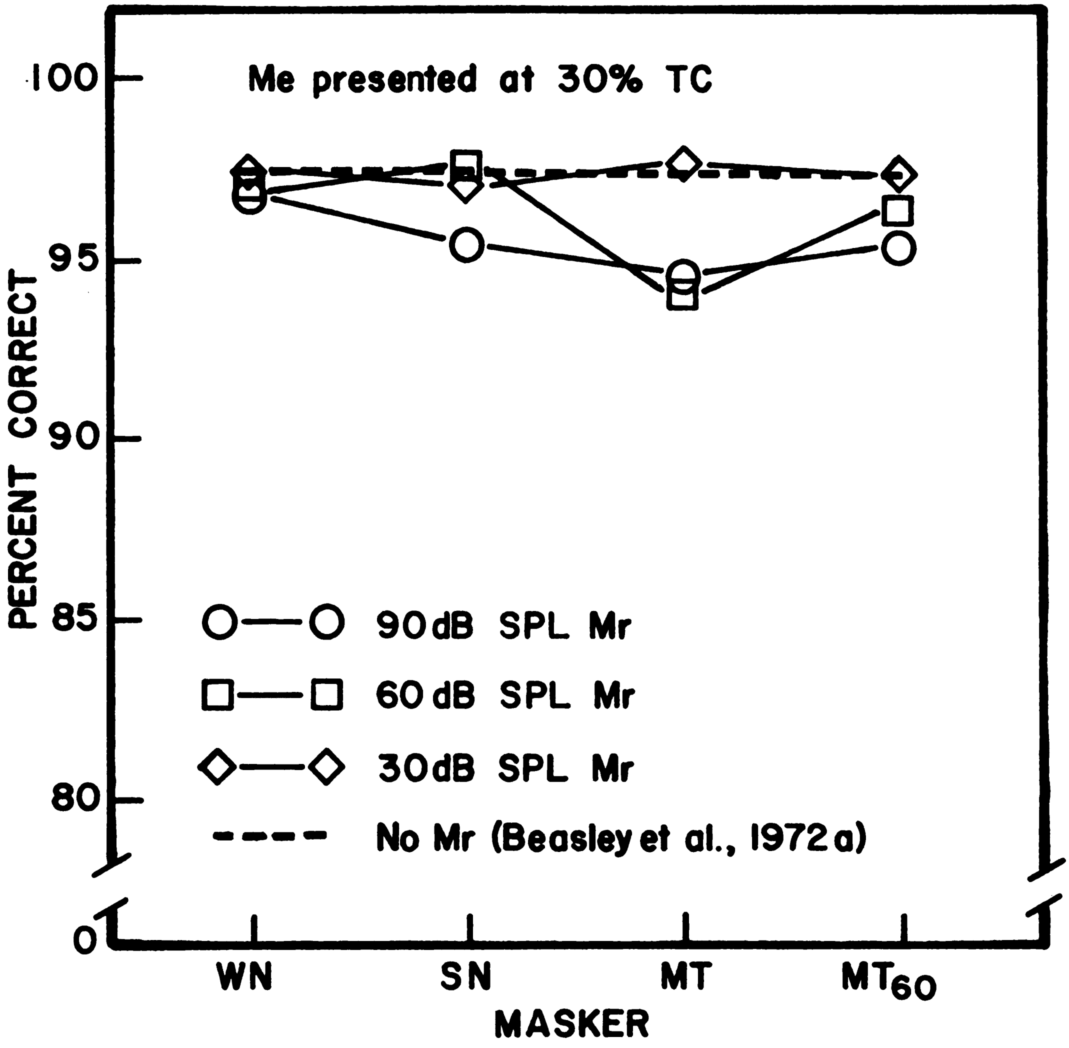

Figure 5. Mean percent correct scores for 30% time-compression as a function of masker type and intensity. The Beasley et al. (1972a) data without contralateral masking are shown for comparison.

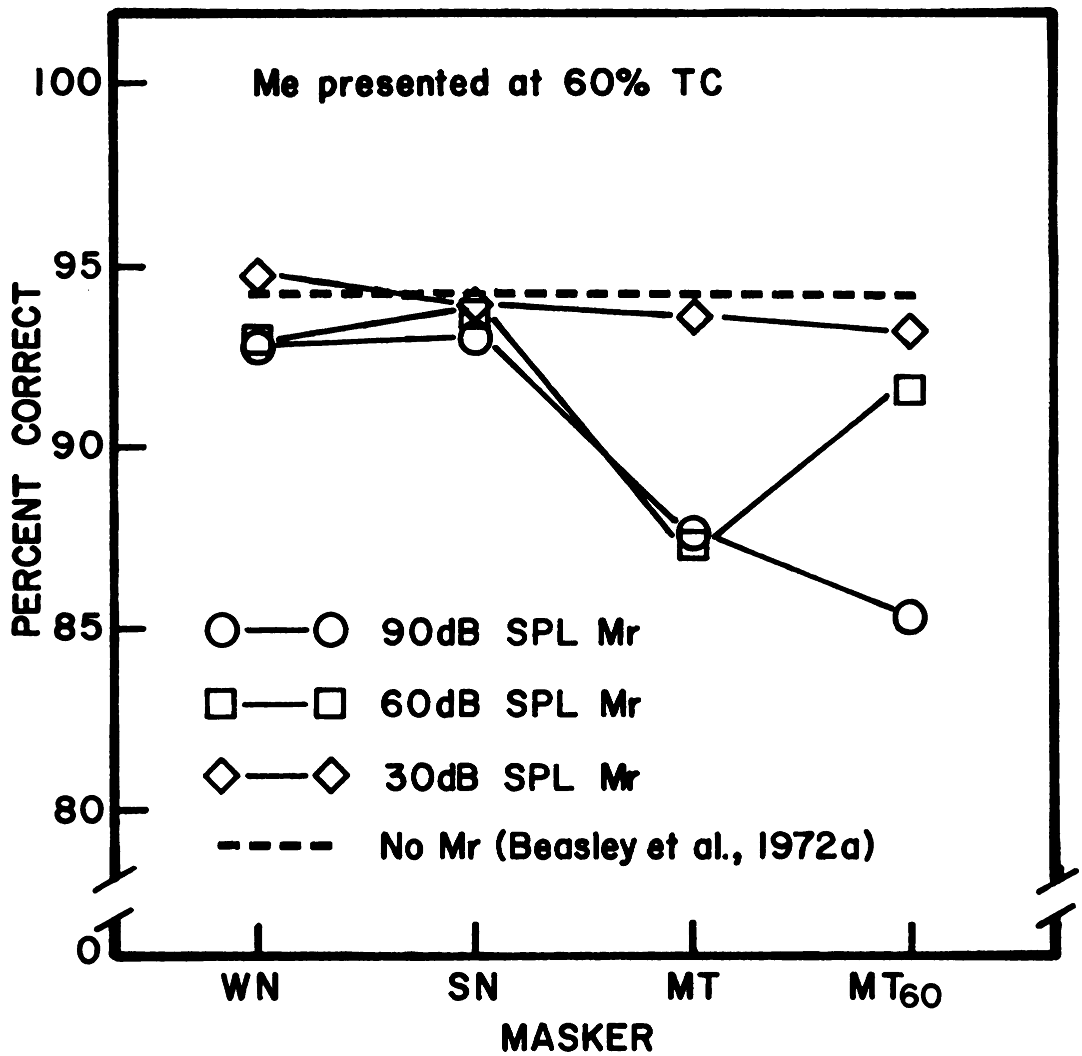

Figure 6. Mean percent correct scores for 60% time-compression as a function of masker type and intensity. The Beasley et al. (1972a) data without contralateral masking are shown for comparison.

of the masker intensity level, the amount of NU-6 time-compression, or the ear to which either stimuli were presented (see Figures 7 and 8).

Multitalker Stimuli as Contralateral Masker

Although the MT masker by itself did not have a significant relationship with NU-6 intelligibility, the combination of this variable with other variables had a significant effect on discrimination scores. Tables 3 and 4 show that statistically significant F values were obtained when the MT masker was combined with TC, TC by Ear, and MrL by TC by Ear. Furthermore, the MT stimuli was the only contralateral masker that caused an ear laterality effect. In order for this effect to emerge, however, it was necessary to include time-compression as part of the combined variable. This finding suggested that the amount of time-compression served to enhance ear laterality. The same observations may be applied to the variable comprised of MrL by TC by Ear by MT, whereby both the amount of time compression and the intensity level of the MT masker enhanced ear laterality.

These results are further depicted in Figures 4 to 7. When NU-6 stimuli were time-compressed by 0%, the effect on intelligibility of MT contralateral masking was negligible (see Figure 4). At 30% time-compression (see Figure 5) discrimination scores decreased approximately 4% when MT masking was presented at 60 and 90 dB SPL. When NU-6 words were time-compressed by 60% (see Figure 6), the MT masker

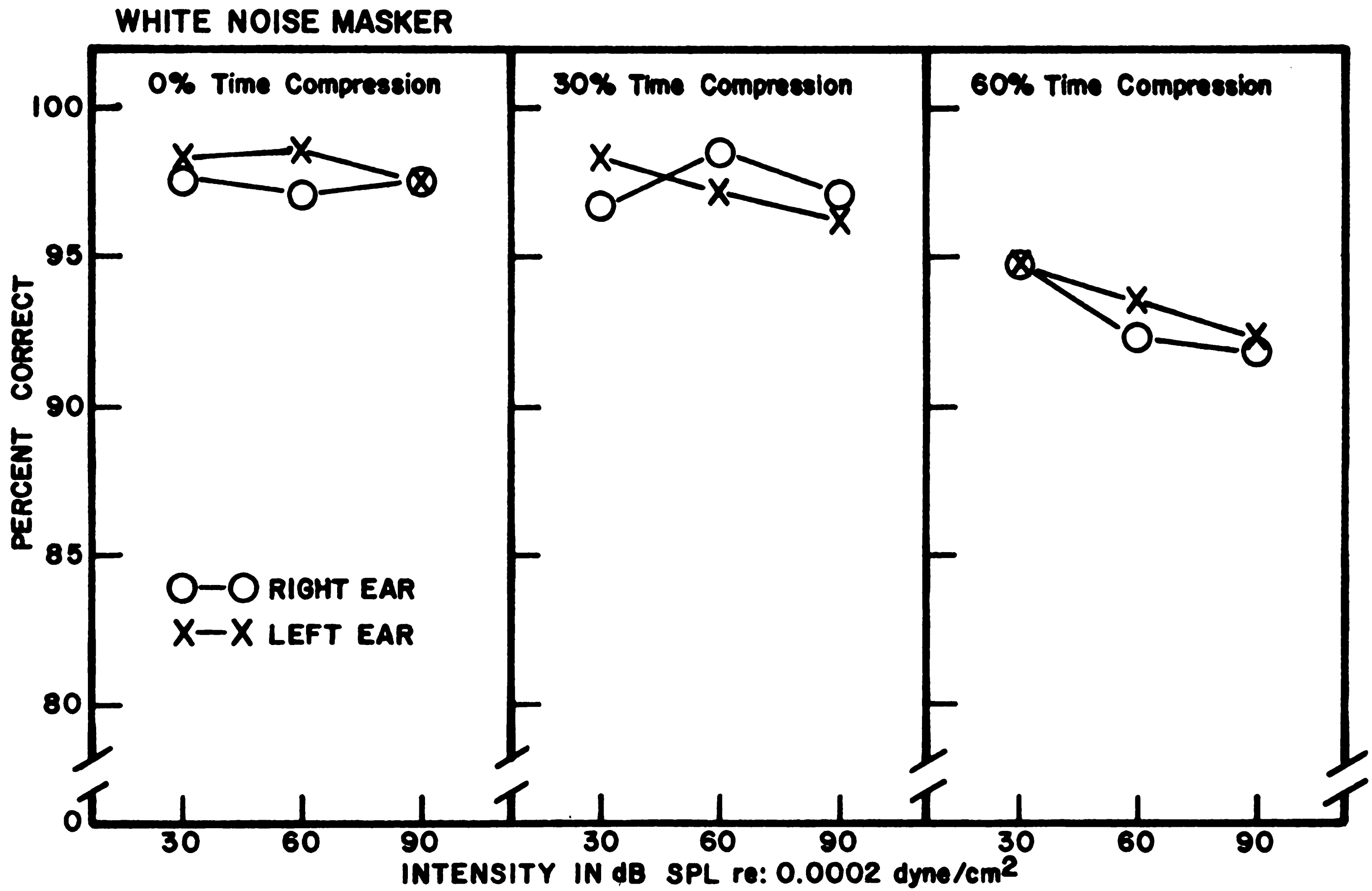

Figure 7. Mean percent correct scores for right and left ears as a function of the intensity of a white noise contralateral masker.

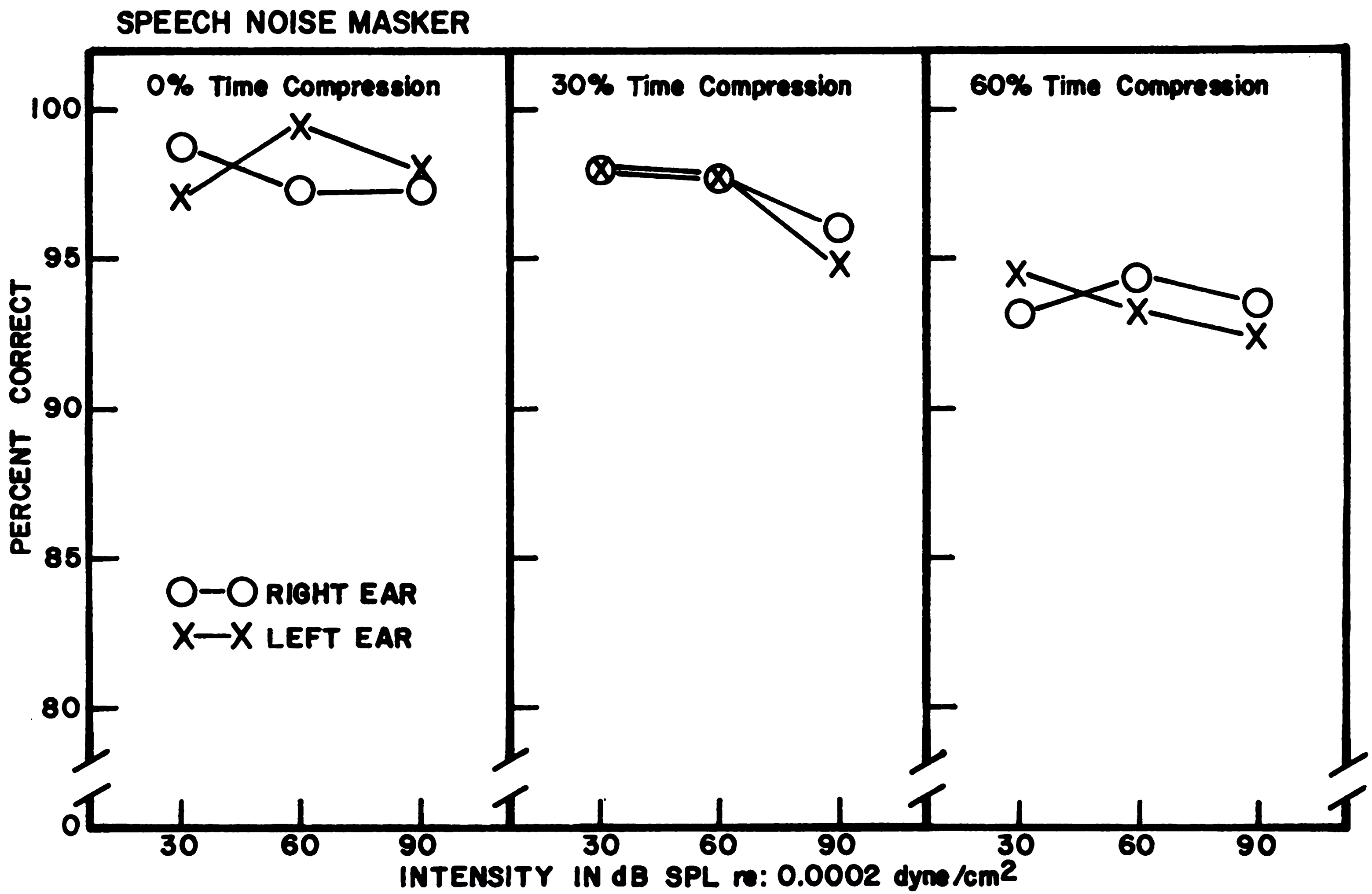

Figure 8. Mean percent correct scores for right and left ears as a function of the intensity of a speech noise contralateral masker.

presented at 60 and 90 dB SPL caused almost a 7% decrease in word intelligibility.

The effects of MT contralateral masking on intelligibility performance as a function of right and left ears and MrL is shown in Figure 9. These data indicated that when the MT stimulus was presented at 60 dB SPL, the right ear yielded better scores than the left ear for each amount of time-compression and that an increase in MrL to 90 dB SPL caused these differences to be enhanced. Further, the right ear advantage increased as the amount of time-compression was increased until, at 60% time-compression a difference of almost 6% occurred between right and left ear performance.

Multitalker 60% Time-Compressed Stimuli as Contralateral Masker

With the exception of ear laterality effects, the relationship between MT60% contralateral masking and percent correct scores was similar to the MT condition. The variables that included the MT60% masker which entered the two regression equations consisted of MrL by TC by MT60% and MT60% by itself. Tables 3 and 4 show that only the combination variable (i.e., MrL by TC by MT60%) had a statistically significant relationship with discrimination performance. While this type masker resulted in decreased discrimination scores as a function of MrL and TC, it did not have a differential effect on ear performance.

The graphic representation of the effects of MT60% contralateral masking on NU-6 intelligibility are shown in

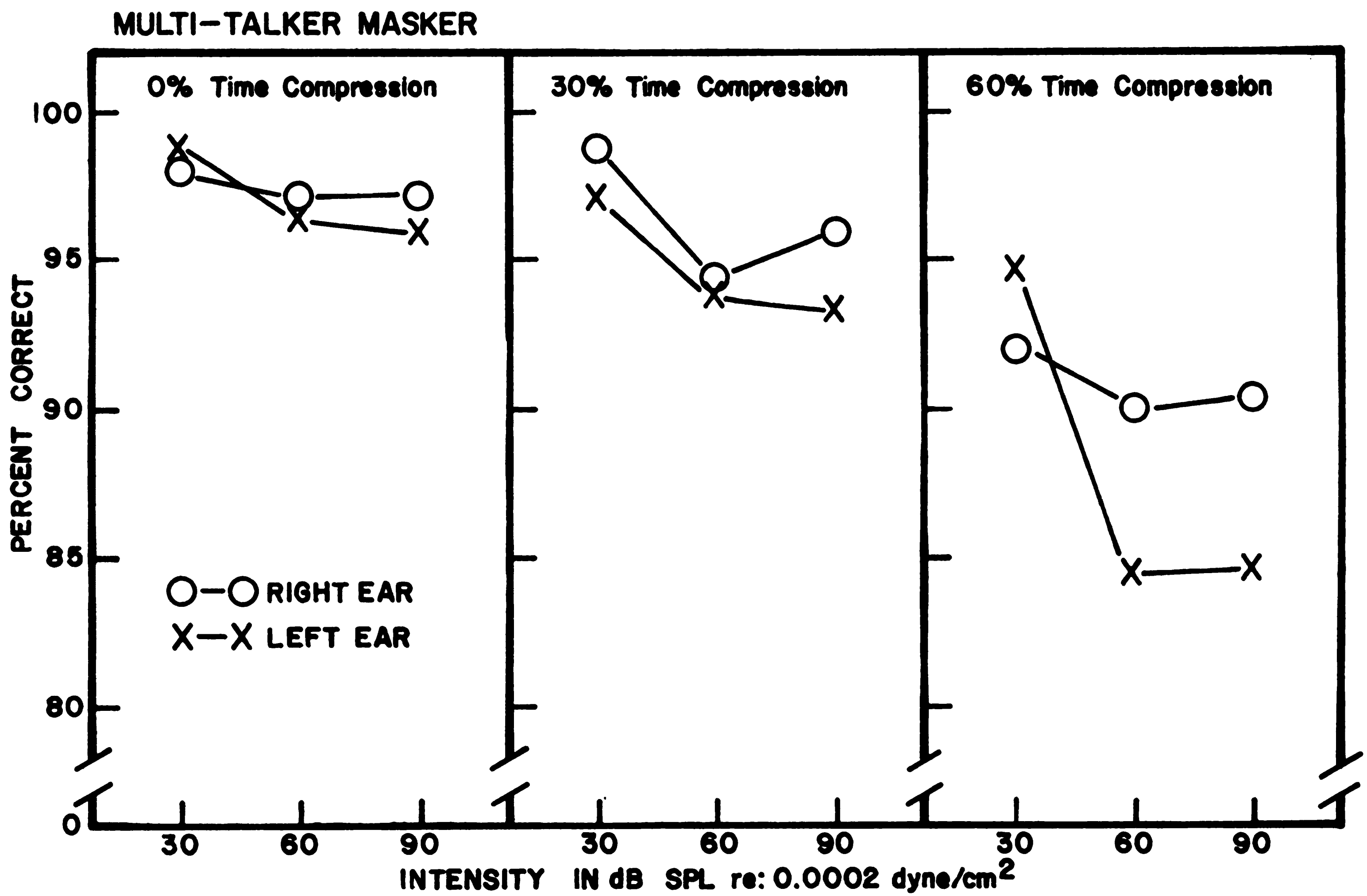

Figure 9. Mean percent correct scores for right and left ears as a function of the intensity of a multitalker 0% time-compressed contralateral masker.

Figures 4 through 6 and Figure 10. Contralateral masking with MT60% stimuli caused only minimal effects when NU-6 words were time-compressed by 0 and 30%. When the NU-6 word lists were time-compressed by 60%, however, the MT60% stimuli caused a significant decrease in speech intelligibility when presented at 90 dB SPL. Interestingly, when the intensity level of this masker was decreased from 90 to 60 dB SPL there was a release from the masking effect on speech intelligibility. This trend was not observed for the MT condition where both 60 and 90 dB SPL resulted in essentially equal masking. Thus, these results indicated that the effects of MT60% contralateral masking were similar to those observed for the white and speech noise maskers, except when the NU-6 stimuli were time-compressed by 60% and the MT60% masker was presented at 90 dB SPL.

Summary

The stepwise multiple linear regression analysis used in this investigation revealed that stages beyond the eighth step did not contribute significantly to R. For the eight variables included in each equation, only five were statistically significant at the 0.05 confidence level. Three of these five variables included a combination of MT, whereas only one included the MT60% masker. The other variable, time-compression, was not independently germane to the questions asked in this study. The Beta weights associated with each variable provide an estimate of the overall impact

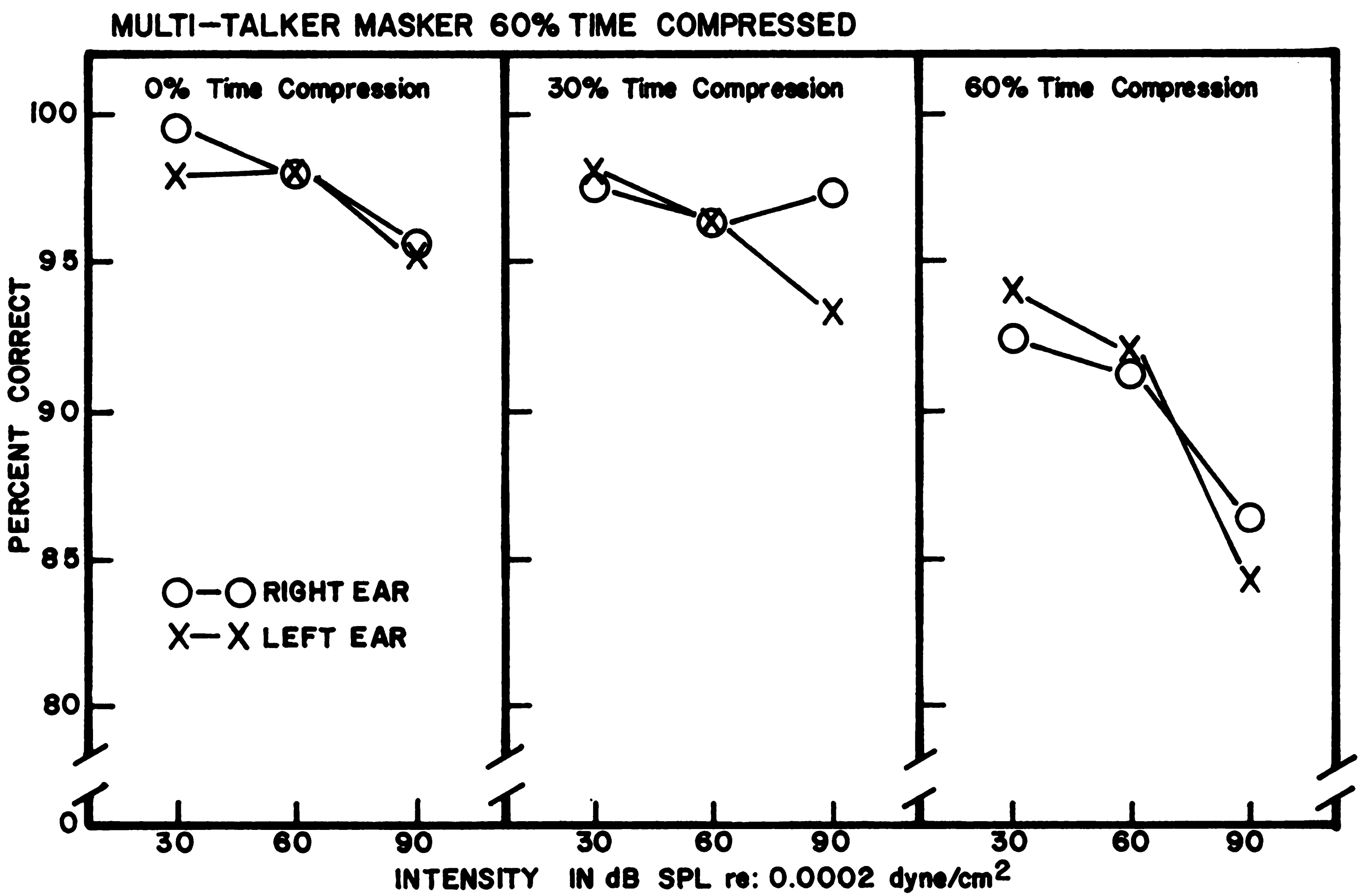

Figure 10. Mean percent correct scores for right and left ears as a function of the intensity of a multitalker 60% time-compressed contralateral masker.

of a specific variable on R. Tables 3 and 4, therefore, suggested that TC by Ear by MT had the greatest influence on percent correct scores, followed by TC by MT, TC, and MrL by TC by MT60% and MrL by TC by Ear by MT, respectively.

CHAPTER IV

DISCUSSION

The results of this investigation indicated that the effects of contralateral masking on the intelligibility of time compressed NU-6 speech discrimination lists were dependent upon the type of masking stimuli, the intensity level of the masker, and the amount of NU-6 time-compression. White noise and speech noise contralateral maskers were found to have no appreciable effect on speech intelligibility. Conversely, multitalker contralateral maskers had a statistically significant impact on discrimination scores when combined with other variables. These findings have several important implications.

Implications for Clinical Audiology

In clinical settings, white noise and speech noise are commonly used as contralateral maskers in speech audiometric evaluations. Previous research (Martin et al., 1965; Martin, 1966; Young and Harbert, 1970; Spencer and Priede, 1974; Jerger and Jerger, 1975) indicated that contralateral masking while causing a change in speech reception threshold, did not have any substantial effect on speech discrimination

scores obtained with non-distorted speech stimuli. The results of this investigation were in agreement with these previous findings and further extended such observations to temporally distorted (i.e., time compressed) speech materials.

Hence, it appears that white noise and speech noise may continue to be used as contralateral maskers in speech audiometric testing. Moreover, the absence of ear laterality effects under conditions of contralateral masking with white noise and speech noise stimuli support the contention of Beasley et al. (1972b) that time compressed NU-6 words can be used in a monotic listening task without results being confounded by laterality effects. These recommendations should not, however, preclude the potential influence of white noise or speech noise on non-test ear performance in pathological populations. Such generalizations await future research.

Implications for Speech Perception

In 1958, Broadbent proposed a model for speech perception that included the concept of an input filter. The purpose of this filter was to allow a single message to be selected from a complex array of messages for further processing. Figure 11 illustrates Broadbent's model as it relates to the auditory system. The input to this model consists of various acoustic signals (i.e., WN and time compressed NU-6 words, SN and time compressed words, MT and time compressed words,

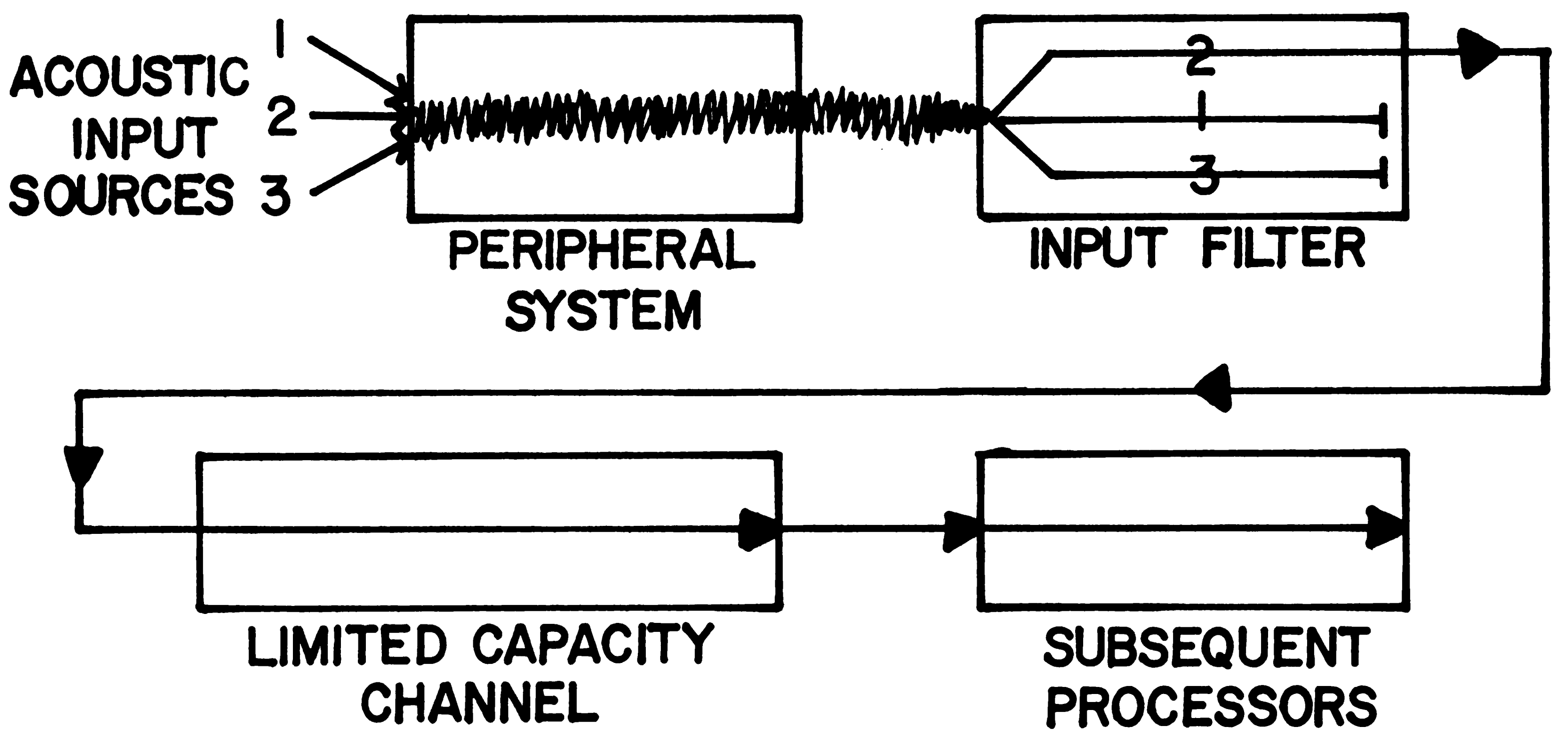

Figure 11. Filter Model of Speech Processing proposed by Broadbent (1958).

or MT60% and time compressed words) that enter the peripheral auditory system and are processed via the cochlea and VIIIth auditory nerve as a disorganized mass of neural impulses. At the filter stage, neural impulses are separated and a selective procedure allows one message to be processed through subsequent stages to eventually an acceptable level of intelligibility. According to Broadbent, this selective filtering is necessary because the next stage is characterized by limited capacity storage.

Broadbent proposed that the filtering process, or the separation of neural impulses into individual messages, was accomplished through the use of distinctive features. In the auditory sense, the distinctive features relate to acoustic cues that are employed during binaural localization (i.e., NU-6 stimuli to one ear and masking to the other ear), and are related to harmonic characteristics (i.e., fundamental frequency and vowel formants or masker frequency spectra) and temporally - based transitional characteristics (i.e., consonant-to-nucleus-to-consonant durations). The efficiency of the filter, therefore, depends upon the similarity and number of features that must be scanned in order to distinguish between messages. That is, filter efficiency will decrease as the number of acoustic cues increase and as they become more similar and result in interference.

The results of the present investigation provide data that illustrate how the filtering process may work. For

example, the method of stimuli presentation comprised a binaural listening task where NU-6 words were presented to one ear and the various maskers to the other ear. In the case where contralateral masking consisted of either WN or SN the greatest difference in mean scores for any condition was 2.2%. Since it was only necessary to distinguish between two input messages (i.e., NU-6s and contralateral masker) that provided dissimilar acoustic features, the filtering task was easy. As a result, white and speech noise contralateral masking did not adversely affect filtering efficiency and NU-6 intelligibility remained unchanged.

For multitalker maskers, however, the filtering task was more complex. Although binaural stimulation remained, the competing messages were similar to harmonic content and temporal relationship. Further, the filtering task was made even more difficult since there were now a total of five competing messages that needed to be deciphered before subsequent processing of the NU-6 stimuli could take place. Consequently, in these conditions the input filtering efficiency was decreased resulting in a loss of intelligibility for NU-6 words.

The different effects observed between the two multitalker maskers may also be explained in terms of the filtering process. Recall that the MT masker generally caused a greater decrease in speech intelligibility when the NU-6 words were time-compressed by 0 and 30% as compared to the MT60% masker (see Figures 4 and 5, pages 39 and 40). Since

the MT stimulus was not temporally distorted, although unintelligible, it provided cues that were more similar to the 0 and 30% time-compressed NU-6 words than were the cues associated with the MT60% stimuli. Hence, the filtering process for these conditions was taxed to a greater extent when MT stimuli were present than when MT60% stimuli competed with NU-6 words.

The same rationale can be employed when the NU-6 test was time-compressed by 60% (see Figure 6, page 41) and the two multitalker maskers were presented at 30 and 60 dB SPL. When multitalker maskers were at 90 dB SPL, however, the MT60% stimuli resulted in a slightly greater decrease in speech intelligibility. Apparently, the increase in intensity served to alter the relationship of features available to the filter in a manner that caused efficiency to decline. It may be speculated that the increased intensity in conjunction with time compression parameters resulted in acoustic cues that were similar for this condition, and thus, caused the additional decrease in intelligibility. Further research, however, is necessary before any conclusions may be reached relative to these contentions.

The ear laterality effects observed in the present investigation were of the same order (i.e., right ear advantage) and magnitude as those reported previously for dichotic listening tasks (Berlin, 1972; Kimura, 1967). The significant ear effects that resulted for only the MT masker may suggest that ear laterality is bound by temporal factors.

Again, future research on this topic may help to elucidate the interaction of contralateral MT masking and ear laterality.

Implications for Further Research

The results of the present investigation provide data that should serve to stimulate additional research. Since the scope of this study was limited to a normal hearing population, generalizations beyond this population appear hazardous. Consequently, similar research needs to be conducted with pathological subject samples. For example, both peripheral and central type auditory disorders should be examined in order to determine the relationship between hearing loss, speech processing, and the effects of contralateral masking. The investigation of auditory pathologies confined to either the brain stem or temporal cortex would appear especially rewarding in view of potential implications to filter processing.

The release from masking observed in this investigation for the MT60% masker as a function of MrL and TC needs to be systematically investigated through the use of several degrees of time compression covaried with different intensity presentation levels of both the maskee and masker. The somewhat restricted range of these parameters in the present investigation have only provided limited information concerning such inter- and intrarelationships. The findings of this study, however, suggest that the observed release from

masking may be related to temporal components of the masker that need to be differentiated from the confounding effect of intensity level.

It may be of interest to examine the afore-going variables in terms of their potential implications for hearing aid users. For example, the ear laterality effects noted for non-distorted multitalker stimuli suggests that the right ear should be considered for amplification in cases where there are not substantial differences between audiometric data for the two ears. Research in this area may provide information about the most suitable mode of amplification (i.e., binaural vs monaural) in respect to specific listening conditions.

Finally, the effect of contralateral masking on speech intelligibility with maskers that retain temporal parameters but do not consist of speech (i.e., modulated white or speech noise) may provide information about the relationship between temporal factors and speech perception. Since modulated noise would be devoid of meaning as compared to multitalker stimuli, the findings of such an investigation may more clearly define the temporal boundaries associated with the filter process.

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APPENDICES

APPENDIX A

METHOD AND PROCEDURE USED TO OBTAIN FREQUENCY SPECTRA OF MASKING STIMULI

APPENDIX A

METHOD AND PROCEDURE USED TO OBTAIN FREQUENCY SPECTRA OF MASKING STIMULI

To obtain the frequency spectra produced by the four masking stimuli, each masker was generated in the same manner used during experimental sessions. The output signal from the TDH 39-10Z earphone was then submitted to third band octave filtering and the spectra plotted as a function of intensity in dB.

Apparatus

The left TDH 39-10Z earphone and associated MX 41/AR cushion were coupled to an artificial ear (Bruel and Kjaer, type 4152). The pressure microphone (Bruel and Kjaer, type 4144) was connected to an audio-frequency spectrometer (Bruel and Kjaer, type 2112). In turn, the spectrometer was linked to a graphic level recorder (Bruel and Kjaer, type 2305). Third band octave measurements were made at centered frequencies from 25 Hz to 40,000 Hz. The frequency bandwidth varied from 5.8 Hz at centered frequency 25 Hz to 9200 Hz at centered frequency 40,000 Hz.

Method and Procedure

The intensity of each masker was initially adjusted to read 90 dB SPL (re: 0.0002 dyne/cm^2) on the linear scale of the spectrometer. For speech and white noise stimuli the 90 dB SPL reading was obtained directly from the noise; whereas, for the multitalker stimuli the 1000 Hz calibration tone was used for the 90 dB SPL adjustment.

The 1000 Hz calibration tone that preceded each multitalker masker was recorded at a level consistent with the average of the frequent intensity peaks throughout the duration of the specific masker. For the purpose of third band filtering, however, three segments that were considered representative of the total masker recording were selected for analysis. Each segment, 3.8 seconds in duration, was fabricated into a "loop" that was continuously played back via the experimental instrumentation.

With the third octave band filtering network of the audio-frequency spectrometer engaged, the filtered signals from the TDH 39-10Z earphone was automatically charted on the graphic level recorder. White and speech noise measurements were made only once and the three measures for each multitalker masker were averaged to obtain frequency spectra. The results of these measurements are shown in Figure 1, Page 23.

APPENDIX B

STANDARDIZED INSTRUCTIONS PROVIDED TO SUBJECTS PRIOR TO EXPERIMENTAL SESSIONS

APPENDIX B

STANDARDIZED INSTRUCTIONS PROVIDED TO SUBJECTS PRIOR TO EXPERIMENTAL SESSIONS

Now, what you are going to hear is a list of fifty stimuli items. Each item will be made-up of the phrase "You will" followed by a word, for example "cow". What you will hear then is "You will say cow". What I want you to do is to print the last word that you hear for each item. In the example "You will say cow", you would print C - O - W, cow. Now, the items are not numbered, but there is enough time between each one so that you should not have any trouble following along and printing your answer on this form. Do you have any questions? Alright, now you will only hear the items in your (right/left) ear. In your other ear you will hear some noise. Don't pay any attention to the noise and pay close attention to each item. I should caution you that it may sound as if the man is talking extremely fast. Don't let that bother you, just do the best you can do. If necessary, feel free to guess, even if you have to make a wild guess. Any other questions? Are you ready?

APPENDIX C

ANSWER FORM

APPENDIX C

ANSWER FORM

Name ______________ NU#6 LIST _____% TC _____ Mr _____ SPL _____

1. ______________	26. ______________
2. ______________	27. ______________
3. ______________	28. ______________
4. ______________	29. ______________
5. ______________	30. ______________
6. ______________	31. ______________
7. ______________	32. ______________
8. ______________	33. ______________
9. ______________	34. ______________
10. ______________	35. ______________
11. ______________	36. ______________
12. ______________	37. ______________
13. ______________	38. ______________
14. ______________	39. ______________
15. ______________	40. ______________
16. ______________	41. ______________
17. ______________	42. ______________
18. ______________	43. ______________

19. ______________________ 44. ______________________

20. ______________________ 45. ______________________

21. ______________________ 46. ______________________

22. ______________________ 47. ______________________

23. ______________________ 48. ______________________

24. ______________________ 49. ______________________

25. ______________________ 50. ______________________

Actual answer form was on one page.

APPENDIX D

EQUATIONS USED IN MULTIPLE LINEAR REGRESSION ANALYSIS

APPENDIX D

EQUATIONS USED IN MULTIPLE LINEAR REGRESSION ANALYSIS

$$\begin{aligned} X_1 = {} & B_1X_2 + B_2X_3 + B_3X_4 + B_4X_5 + B_5X_7 + B_6X_8 + B_7X_{23} + \\ & + B_8X_{24} + B_9X_{25} + B_{10}X_{27} + B_{11}X_{28} + B_{12}X_{35} + \\ & + B_{13}X_{37} + B_{14}X_{38} + B_{15}X_{45} + B_{16}X_{47} + B_{17}X_{48} + \\ & + B_{18}X_{234} + B_{19}X_{235} + B_{20}X_{237} + B_{21}X_{238} + B_{22}X_{345} + \\ & + B_{23}X_{347} + B_{24}X_{348} + B_{25}X_{2345} + B_{26}X_{2347} + \\ & + B_{27}X_{2348} + E. \end{aligned}$$

$$\begin{aligned} X_1 = {} & B_1X_2 + B_2X_3 + B_3X_4 + B_4X_6 + B_5X_7 + B_6X_8 + B_7X_{23} + \\ & + B_8X_{24} + B_9X_{26} + B_{10}X_{27} + B_{11}X_{28} + B_{12}X_{36} + \\ & + B_{13}X_{37} + B_{14}X_{38} + B_{15}X_{46} + B_{16}X_{47} + B_{17}X_{48} + \\ & + B_{18}X_{234} + B_{19}X_{236} + B_{20}X_{237} + B_{21}X_{238} + \\ & + B_{22}X_{346} + B_{23}X_{347} + B_{24}X_{348} + B_{25}X_{2346} + \\ & + B_{26}X_{2347} + B_{27}X_{2348} + E. \end{aligned}$$

Where: X_1 = percent correct score, X_2 = masker intensity level, X_3 = time-compression, X_4 = ear, X_5 = WN, X_6 = SN, X_7 = MT, X_8 = MT60%, X_{23} to X_{2348} = variable combinations, E = error, and B_1 to B_{27} = Beta weights.

APPENDIX E

SUBJECTS' RAW SCORES FOR EACH EXPERIMENTAL CONDITION

APPENDIX E

SUBJECTS' RAW SCORES FOR EACH EXPERIMENTAL CONDITION

CONTRALATERAL MASKER AT 30 dB SPL

Maskee at 0% Time-Compression

Subjects	Ear	Percent Correct WN	SN	MT	MT60%
1	R	100	98	96	100
2	L	98	94	100	100
3	R	94	96	100	98
4	L	100	100	98	98
5	R	96	100	96	100
6	L	98	98	100	96
7	R	100	100	98	100
8	L	96	96	100	100
9	R	98	100	100	100
10	L	100	98	96	96

Maskee at 30% Time-Compression

Subjects	Ear	Percent Correct WN	SN	MT	MT60%
11	R	98	96	100	96
12	L	100	100	94	98
13	R	96	100	96	100
14	L	100	98	98	100
15	R	92	100	100	94
16	L	98	98	94	96
17	R	100	96	98	98
18	L	94	94	96	100
19	R	98	98	100	98
20	L	100	94	98	96

Maskee at 60% Time-Compression

Subjects	Ear	WN	Percent Correct SN	MT	MT60%
21	R	88	98	96	98
22	L	98	94	92	96
23	R	98	94	94	94
24	L	98	100	96	92
25	R	96	100	98	96
26	L	88	83	90	90
27	R	96	86	90	98
28	L	96	90	94	92
29	R	96	94	96	96
30	L	94	100	90	92

CONTRALATERAL MASKER AT 60 dB SPL

Maskee at 0% Time-Compression

Subjects	Ear	WN	Percent Correct SN	MT	MT60%
31	L	98	100	96	100
32	R	96	98	100	96
33	L	100	94	96	100
34	R	94	94	98	98
35	L	100	98	96	96
36	R	100	96	94	100
37	L	96	100	98	100
38	R	100	100	98	98
39	L	100	98	96	100
40	R	98	98	94	98

Maskee at 30% Time-Compression

Subjects	Ear	WN	Percent Correct SN	MT	MT60%
41	L	96	98	96	94
42	R	90	98	94	98
43	L	96	98	94	98
44	R	98	96	90	96
45	L	96	94	88	96
46	R	98	96	100	94
47	L	96	100	100	98
48	R	94	100	92	96
49	L	98	98	94	96
50	R	98	100	96	98

Maskee at 60% Time-Compression

Subjects	Ear	WN	Percent Correct SN	MT	MT60%
51	R	92	98	94	94
52	L	94	86	84	92
53	R	94	92	86	96
54	L	94	94	86	90
55	R	92	100	90	82
56	L	94	98	78	92
57	R	90	90	90	100
58	L	94	98	92	90
59	R	94	92	90	84
60	L	92	90	82	96

CONTRALATERAL MASKER AT 90 dB SPL

Maskee at 0% Time-Compression

Subjects	Ear	WN	Percent Correct SN	MT	MT60%
61	R	98	96	98	96
62	L	100	100	98	96
63	R	94	96	90	96
64	L	98	96	98	98
65	R	98	100	98	94
66	L	98	96	90	96
67	R	98	98	100	98
68	L	96	92	96	98
69	R	100	96	100	94
70	L	90	100	98	94

Maskee at 30% Time-Compression

Subjects	Ear	WN	Percent Correct SN	MT	MT60%
71	L	94	96	98	94
72	R	98	96	98	100
73	L	96	92	88	94
74	R	96	92	98	100
75	L	98	96	86	92
76	R	96	96	90	98
77	L	100	98	96	92
78	R	98	100	96	94
79	L	94	92	96	94
80	R	98	96	98	94

Maskee at 60% Time-Compression

		Percent Correct			
Subjects	Ear	WN	SN	MT	MT60%
81	R	88	92	90	74
82	L	98	90	82	90
83	R	94	86	88	86
84	L	80	94	86	84
85	R	88	90	88	90
86	L	96	90	94	94
87	R	100	96	84	84
88	L	94	96	92	88
89	R	94	98	84	88
90	L	92	98	90	84

APPENDIX F

TABLE OF MEAN PERCENT CORRECT SCORES FOR EACH EXPERIMENTAL CONDITION

Table 5. --Average Percent Correct Scores for each Time-Compression Ratio, Masker Type, Masker Intensity Level, and Right and Left Ears.

Masker Intensity Level	Percent Time-Compression	White Noise			Speech Noise		
		Right	Left	Total $\bar{X}$	Right	Left	Total $\bar{X}$
	0%	97.6	98.4	98.0	98.8	97.2	98.0
30 dB SPL	30%	96.8	98.4	97.6	98.0	98.0	98.0
	60%	94.8	94.8	94.8	93.2	94.4	93.8
	Total $\bar{X}$	96.4	97.2	96.8	96.8	96.5	96.6
	0%	97.2	98.8	98.0	97.2	99.2	98.2
60 dB SPL	30%	98.6	97.2	97.9	97.6	97.6	97.6
	60%	92.4	93.6	93.0	94.4	93.2	93.8
	Total $\bar{X}$	96.0	96.5	96.2	96.4	96.6	96.5
	0%	97.6	97.6	97.6	97.2	98.0	97.6
90 dB SPL	30%	97.2	96.4	96.8	96.0	94.8	95.4
	60%	92.0	92.8	92.4	93.6	92.4	93.0
	Total $\bar{X}$	95.6	95.6	95.6	95.6	95.0	95.3