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SEMANTIC CONTENT OF SSI PERFORMANCE

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THE EFFECTS OF COMPETING MESSAGE SEMANTIC CONTENT ON SSI PERFORMANCE

by

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ABSTRACT

The Effect of Competing Message Semantic Content
on SSI Performance Scores

Thirty-six normal-hearing adult subjects served in an experiment that examined the effects of competing message semantic content on SSI psychometric function slope values and 50% masking efficiency levels. To avoid the confounding variable of temporal discontinuity inherent in a single-talker competing message, the study utilized multi-talker stimuli and stimuli derived from the multi-talker materials. The effect of competing message semantic content was investigated by comparing SSI performance under six different competing message conditions. Two competing messages allowed examination of semantic content effect in a single-ground competitor while four others allowed examination of semantic content effect in foreground-background stimuli. The six competing messages were as follows: (1) multi-talker, consisting of eight equally prominent talkers (MT 8); (2) MT 8 in background plus one perceptually prominent foreground talker (MT 8 + 1); (3) dynamic envelope noise derived from the MT 8 (DEN MT); (4) DEN MT in background plus single-talker in foreground (DEN MT + 1); (5) MT 8 in background with modulated single-talker noise in foreground (MT 8 + DEN 1); and (6) DEN MT in background with DEN 1 in foreground (DEN MT + DEN 1).

A 25-item four-alternative forced-choice response paradigm was used to reduce test variability associated with small test size. The

present findings indicate competing message semantic content had little, if any, effect on psychometric function slope value. However, competing message semantic content did serve to increase masking efficiency. Semantic content in a single-ground stimulus caused 2.6 dB excess masking. Semantic content in foreground-background competitors caused excess masking of 1.0 dB when it occurred in the temporally variable foreground only, 2.8 dB when it occurred in the temporally continuous background only, and 8.9 dB when it occurred in both grounds.

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CHAPTER I

BACKGROUND

INTRODUCTION

The Synthetic Sentence Identification Test (SSI) was devised to systematically examine the role of temporal processing in speech intelligibility (Speaks and Jerger, 1965). Single unit speech stimuli, including nonsense syllables, phonetically balanced monosyllables, and disyllabic words are of insufficient duration for use in studies involving the parameter of time. Conversational sentences are undesirable because: (1) real sentences may convey meaning or be identifiable by only one or two key words; and (2) message set equivalency is difficult to achieve due to the difficulty of controlling the factors of word familiarity, sentence length, word length, and syntactic structures (Speaks and Jerger, 1965). The construction of artificial sentences according to specific predetermined rules avoids the problems inherent in single word or real sentence stimuli.

Speaks and Jerger (1965) employed Miller's (1951) method of generating artifical (synthetic) sentences in which each successive word is selected solely on the basis of the conditional probabilities of word sequence without regard to overall sentence meaning. In other words, the selection of each new word is determined by the preceding word or words in one of three ways or orders of

approximation to real sentences. Synthetic sentences can be constructed by: (1) choosing successive words from a common pool (first-order sentences); (2) choosing successive words based on a preceding word (second-order sentences), and (3) choosing successive words based on the preceding pair of words (third-order sentences). All words are selected from a pool of the 1000 most common words in the English language (Thorndike and Lorge, 1944). Sentence length (allowable number of words and syllables) is pre-determined. Third-order sentences are characterized by greater syntactical constraints than either first or second-order sentences and thus more closely approximate real sentences. The majority of research involving the Synthetic Sentence Identification Test (SSI) has focused on third-order sentence stimuli.

The SSI test as described by Speaks and Jerger (1965) and Jerger (1970a) examines an individual's ability to identify a syntactically constrained sentence, given a ten-alternative closed message set. Identification of synthetic sentential stimuli in the ten-alternative forced-choice paradigm is a departure from traditional test tasks which require repetition of verbal stimuli. The paradigm allows for the determination of learning or practice effects and minimizes experimenter error through the utilization of automatic data collection procedures (Speaks and Jerger, 1965).

The experimental procedure is similar to that of traditional discrimination testing (Fletcher and Steinberg, 1929; Miller, 1947; Egan, 1948) in that intelligibility is determined as a function of signal intensity (i.e., psychometric function). Speaks, Jerger, and Jerger (1966) found the general shape of the resulting function to be

sigmoidal, with performance scores rising steeply from 20% to 80% correct within a 6 dB range (Speaks, 1967a). This slope reflects the relative simplicity of the identification task in quiet and subsequently fails to differentiate between varying abilities to discriminate speech (Jerger, Speaks, and Trammell, 1968). A flatter psychometric function slope would be required to differentiate among subject groups.

Several researchers have modified the SSI test procedures in an attempt to flatten the slope of the psychometric function for the purpose of making a more clinically useful test instrument. Speaks, Jerger, and Jerger (1966) used low pass filtered synthetic sentences (F_C = 500 Hz) as stimuli and found no appreciable effect on the shape or slope of the resulting psychometric function. Speaks (1967b) employed low-pass filtered stimuli (F_C = 125 Hz) and high-pass filtered sentence stimuli (F_C = 7000 Hz). The psychometric function again remained unchanged in shape and slope. Other studies degraded the stimuli via broadband masking noise (Speaks and Karmen, 1967; Dirks and Wilson, 1969), also with no significant effect on the shape and slope of the psychometric function. In these studies, the psychometric function is observed to shift along the abscissa to a degree proportional to either the amount of filtering or the magnitude of the signal-to-noise ratio of the ipsilateral masking noise. Although both the filtering process and the addition of masking noise elevate the sound pressure level necessary for subjects to begin to be able to identify stimuli, once this point is reached, the psychometric function rises quickly.

The SSI task also has been degraded through introduction of a continuous speech competing message (Speaks, Karmen, and Benitez, 1967; Jerger, Speaks, and Trammell, 1968; Dirks and Wilson, 1969; Dirks and Bower, 1969; Garstecki and Mulack, 1974; Goldschmidt, 1979). Speaks, Karmen, and Benitez (1967) were first to discover that the steepness of the SSI psychometric function could be considerably flattened by the introduction of a single-talker competing message. In this case, the same speaker was used for both the competing and the primary (SSI) message. The flattening of the psychometric function was attributed to "random masking" (i.e., masking components occurring randomly in time) and the disruptive features of competing speech. Whereas electronically-generated broadband noise was a very efficient masker in terms of shifting the psychometric function along the abscissa, the single-talker competing message was efficient in flattening the function along the ordinate. Speaks, Karmen, and Benitez (1967) confirmed the stability of the SSI sentence task with a constant message-to-competition ratio (MCR) over a wide range of presentation levels. Thus, test difficulty was increased with selection of various presentation levels without the problems of level-dependency inherent to the quiet presentation (no competing message) situation.

Four studies (Dirks and Bower, 1969; Garstecki and Mulac, 1974; Trammell and Speaks, 1970; Goldschmidt, 1979) investigated the possible effects of the disruptive features of semantic content (meaning) within the competing speech message. Dirks and Bower eliminated the effect of semantic content in a single-talker competing message by reproducing it backwards. No difference in SSI

performance was found between the competing message forward (CMF) and competing message backward (CMB) conditions at MCRs of -30 dB, -24 dB, -18 dB, and -12 dB while holding the primary message at a constant 40 dB SPL. Dirks and Bower concluded that the semantic content of competing message stimuli does not affect SSI performance.

Three other studies found otherwise. Goldschmidt (1979) used a single-talker competing message and observed decreased SSI performance with CMF as compared to CMB at MCRs of -12 dB and -24 dB. The primary message was delivered at a constant 40 dB SPL and the MCR was varied. Garstecki and Mulac (1974) used a multi-talker competing message and also found poorer CMF than CMB scores with the primary and competing messages both delivered at 40 dB SPL (0 dB MCR). Their competing message consisted of a combination of two separate group discussions (3-5 speakers per group). The spectrum of the multi-talker competing message used by Garstecki and Mulac almost certainly differed from the single-talker spectrum used by Dirks and Bower (1969) and by Goldschmidt (1979). Trammell and Speaks, (1970), who also used a single-talker competing message, found poorer CMF than CMB scores at MCRs of -30, -20, and -10 dB.

Other methodological differences which may account for the discrepancy in results include the use of different test stimuli, levels of subject sophisitication, response modes, and presentation modes. Dirks and Bower employed monaural earphone presentations of ten sentences arranged in several random orders with an ipsilateral competing message to trained listeners; Garstecki and Mulac used sound field presentation of two different lists of synthetic sentences

to naive listeners; and Goldschmidt used monaural earphone presentations of six different SSI lists (generated by Chial, 1978) with an ipsilateral competing message to naive listeners. Trammell and Speaks are not specific about their experimental conditions, noting only that the study paralleled those of Dirks and Bower in most respects. Dirks and Bower's listeners may have been overtrained in the primary message set, which may have obscured the semantic content effect. In contrast, Goldschmidt's subjects were trained in the SSI test paradigm but not with the primary message set. This approach is more suitable to the clinical situations for which the SSI test was designed.

Another reason for conflicting results may be the high level of test variability due to the relatively small number of SSI test items. Thornton and Raffin (1978) questioned the use of small-sample tests such as the SSI, noting the increase in variability which occurs when a test is reduced from 25 to 10 items. They concluded that test variability is dependent on both the subject's true score and the number of items on the test. In support, Goldschmidt (1979) found normal subject SSI test ranges as large as 100% and standard deviations nearly one-half the mean values under certain conditions. Speaks and Karmen (1967) also found large standard deviations on the SSI task in quiet and in some noise conditions with normal-hearing subjects. Although Trammell and Speaks (1970) do not report standard deviations, they did note considerable variability by which the CMB scores exceeded CMF scores. Dispersion data are conspicuously absent in all other SSI studies. If the standard deviations in other studies are also large, interpretation would be difficult and clinical application

impossible.

The presentation paradigm employed in most studies involving the SSI presents an additional problem. The forced-choice method is used with a set of ten alternatives. Unlike other forced-choice methods, the items are successively drawn from the set until each one has been presented. Thus, the apriori probability that a given item will be presented varies with the presentation number: for the first presentation, each item has the same probability (.10); for the last presentation, one item as a probability of 1.0 and the others have a probability of .0. Variation in the apriori probability of item presentation may interact with listener memory of prior presentations, as well as the listener's memory of past responses and the confidence with which those responses are made to increase variance in test scores.

Another potential source of test variability which could create discrepancies among SSI studies is the amount of temporal discontinuity in the competing message. Miller (1947) noted that although the long-term spectrum of a single voice is nearly optimal for masking speech, the spectrum at any given moment may be incomplete (void of necessary frequencies) or contain gaps of silence (nonmasked periods). Miller reported that multi-talker (four to eight voices) competing messages are more efficient than single-talker competing in masking PB words at various message-to-competition ratios. The multi-talker competing message produced a steeper function similar to that observed with white noise. Miller was also able to flatten the psychometric function by changing the amplitude envelope of a continuous masking noise. Interestingly, the condition employing the 80%-on 20%-off

masking noise (broadband) produced a psychometric function very much like the single-talker function. This finding indicates that temporal discontinuity alone, apart from any semantic content effects is partially responsible for flattening the PB psychometric function. Even though Miller used PB words rather than SSI material, his results are relevant to SSI studies.

Recent research involving single-talker competing message effects on SSI performance supports Miller's (1947) notion that at any given moment the single-talker masking spectrum may be void of components and thus an imperfect masker. Wofford (1977) found that the intelligibility of a single key word in a synthetic sentence could allow identification of the entire sentence. Based on this finding, Martin and Mussel (1979) predicted subject SSI performance under two conditions: (1) presentation of synthetic sentences with speech noise added to the single-talker competing message and (2) presentation of synthetic sentences with only the single-talker as the competing message. In this study, a subject was given full credit (10%) for a sentence if one or more key words were identified. The assumption was that a subject could determine the correct sentence given one key word. The mean P-I function for predicted SSI performance was shifted and steepened for the noise condition (temporally continuous competing message) relative to the no-noise condition (temporally discontinuous competing message). In other words, the noise condition was more efficient in masking because it contained no temporal gaps.

Several other studies investigating the intelligibility of speech using a variety of verbal materials and experimental procedures have relevance with respect to the issues of semantic content and

temporal discontinuity which are raised in the SSI studies (Carhart, Tillman, and Greetis, 1968; Carhart, Tillman, and Greetis, 1969; Hogan and Hanley, 1963; Pollack and Pickett, 1958; Carhart, Johnson, and Goodman, 1975; Young, Parker, and Carhart, 1975). Carhart, Tillman and Greetis (1968) found that modulated noise and connected sentences produced nearly identical masking effects whether determined by spondee threshold shifts or by intelligibility scores for monosyllabic words. Interestingly, they discovered that combining these two maskers produced an increase in masking efficiency for spondees and shifted monosyllabic word intelligibility functions to a degree not attributable to a simple summation of acoustical power (4.8 dB shift for the spondees and 7.5 dB for the monosyllabic stimuli). In other words, masking was present in excess of that which was physically present. The researchers suggested that "semantic influences," manifested during the simultaneous presentation of the two stimuli may have caused the excess masking. The term "perceptual masking" was later applied to the observed increased masking efficiency secondary to semantic content in the composite background of sentences and modulated noise (Carhart, Tillman, and Greetis, 1969). Perceptual masking is the preferred term in that it denotes only the existence of a phenomenon, whereas the term semantic content implies an underlying mechanism responsible for the phenomenon.

Carhart, Tillman, and Greetis (1969) investigated whether speech intelligibility (as measured by the threshold for spondee words) was more adversely affected by stimuli containing a meaningful speech message than by meaningless modulated noise with comparable dynamic envelope characteristics. The researchers noted that modulation of a

masker, whether the normal modulation of the speech envelope or artificial modulation produced by interrupting white noise, should provide the listener with acoustic "windows" capable of reducing masking efficiency. Indeed, the masking efficiency of both the single-talker competing message and white noise modulated four times per second to a depth of 10 dB with a 50% duty cycle (N^2) were reduced approximately 4 dB compared to the unmodulated white noise (N^1) masking condition. However, they also discovered that a composite background of competing speech (single-talker) and modulated white noise (CN^2) was a more efficient masker than either white noise modulated four times per second by 10 dB with a 75% duty cycle (N^3) or unmodulated white noise (N^1).

The N^3 condition in the Carhart experiment was selected to approximate the dynamic envelope characteristics of CN^2 while remaining free of any semantic content. Comparison of N^3 and CN^2 performance allowed direct assessment of the impact of perceptual masking. Carhart and his colleagues found that masking by the acoustically similar but meaningless stimuli (that is, N^3) was approximately 3 dB less efficient than masking in the CN^2 condition. The CN^2 condition was also superior in masking efficiency to the N^1 (white noise) condition by 2.2 dB even though the CN^3 stimuli contained acoustic "windows" or spaces of silence not present in the N^1 stimuli. These comparisons suggest that the perceptual masking component (semantic content) of the CN^3 stimuli increases masking efficiency more than acoustic windows decrease masking efficiency.

Carhart, Tillman, and Greetis (1969) also investigated perceptual masking in the binaural situation by examining nine types

of background noise across three experimental conditions (homophasis, antiphasis, and time-delay presentation). The most interesting finding with respect to this discussion is the comparison of single-talker plus unmodulated noise composite stimuli and the two-talker stimuli. The latter was found to be a more efficient masker across all three presentation conditions. Thus, the two-talker complex must contribute more perceptual masking than it does masking efficiency (due to temporal gaps).

These findings support the contention that within the single-talker competing stimuli, the two factors of semantic content and temporal discontinuity influence speech intelligibility scores in contradictory rather than complementary ways. That is, semantic content serves to increase perceptual masking efficiency, while temporal discontinuity creates a perceptual advantage which serves to decrease masking efficiency. Several other speech intelligibility studies add support to the findings reported in the Carhart studies (Miller, 1974; Pollack and Pickett, 1958; Hogan and Hanley, 1963; Carhart, Johnson, and Goodman, 1975; Speaks, Wigginton, and Germono, 1971; Young, Parker, and Carhart, 1975).

Pollack and Pickett (1958) and Miller (1947) both report an increase in masking efficiency when a second single-talker competing message is added to an existing single-talker competing message. According to Carhart, Tillman, and Greetis (1968), part of this increase in masking can be attributed to the reduction of the acoustic "window" effect; however, a substantial increase is due to perceptual masking (5.5 to 7.5 dB). The manifestation of perceptual masking is also apparent in a study by Hogan and Hanley (1953). They averaged

intelligibility scores (phonetically balanced monosyllables) for competing voice number over several conditions of rate (compressed and expanded) and singal-to-noise ratio and found increased masking efficiency with voice number increase (from two to four to eight voices).

Recently, Carhart, Johnson, and Goodman (1975) compared masked spondee thresholds obtained in speech spectrum noise modulated by seven different talker combinations, (1, 2, 3, 16, 32, 64, and 128 voices speaking continuous discourse), with those obtained in the respective associated talker combinations. The long term spectra of all stimuli (14) were equalized. This procedure (coupled with the modulation) produced noise maskers which were nearly identical physically to their respective associated talker stimuli, yet were void of semantic content. The findings indicate perceptual masking occurred in all seven combinations of talkers as compared to their respective modulated noise derivatives. The talker situations produced excess masking on the order of 6.2 dB for the one-talker situation, 7.2 dB for the two-talker condition, and 9.8 dB for the three-talker condition. Masking efficiency decreased thereafter with excess masking stabilizing at 3 dB with the 64 talkers. Results of the study clearly indicate that, given identical masking spectra, speech stimuli are more efficient masker than modulated noise. The speech modulated noise has also been used with SSI stimulus.

Speaks, Wigginton, and Germono (1971) compared SSI threshold levels (MCR corresponding to 50% correct) obtained using a single-talker competing message and white noise modulated by the single-talker as the competing messages. The modulated white noise had approximately

22% more area under the envelope function than the competing speech message (i.e., more physical masking ability). SSI thresholds were -29 dB MCR for the competing speech and -36 dB MCR for the noise condition. The results indicate speech to be a more effective masker than the speech modulated white noise. These results are commensurate with the studies of Carhart and associates noted above.

It is important to point out that neither Carhart, Johnson, and Goodman (1975) nor Speaks, Wigginton, and Germono (1971) determined the entire psychometric function. Therefore, it is unknown whether the perceptual masking ability of speech stimuli affects the slope of the psychometric function relative to a physically identical noise stimuli. It is evident that the thresholds (50% correct) of various verbal material (monosyllabic, spondees, synthetic sentences) are more adversely shifted by the competing speech stimuli; but no data are available at the 25% or 75% correct response levels. It could be that the perceptual masking ability of speech stimuli causes a negative shift in performance and also changes the steepness of the slope. In other words, speech stimuli may shift and steepen or flatten the psychometric function relative to an acoustically similar noise condition.

In summary, the SSI psychometric function can be flattened by introducing an ipsilateral single-talker competing message. Most of the flattening effect is probably related to the dynamic amplitude envelope and variable spectrum of the single-talker competing message (i.e., gaps of silence or nonmasking, or low-level speech components). The factor of semantic content may produce perceptual masking which increases masking efficiency relative to a physically identical noise

condition void of semantic content. The increased masking efficiency apparently serves to shift the entire psychometric function. It is not known what effect (if any) semantic content has on the slope of the psychometric function. Recent studies have contributed to an understanding of the impact of temporal discontinuity of a competing message upon SSI performance, but the issue of the effect of semantic content is less well resolved. It is likely that temporal discontinuity effect, differences in the spectra of competing messages, and test method have contributed to variance in performance, thus obscuring effects attributable solely to semantic content.

Also, research has not examined the effect of semantic content within a foreground-background competing message on SSI performance. It is possible that acoustic stimuli having speech in the background and noise in the foreground or noise in the background and speech in the foreground more adversely affect SSI performance than a stimulus with noise in both grounds. In other words, it may be that a foreground-background stimulus with semantic content in at least one ground exhibits more perceptual masking ability than a foreground-background stimulus void of semantic content in both grounds. Furthermore, the expected semantic content effect may be even greater when semantic content occurs in both grounds of a foreground-background competing message.

In order to accurately measure the difference in perceptual masking ability of the respective stimuli it would be necessary to make the stimuli physically identical to each other with the only difference being the presence or absence of semantic content. Use of multi-talker speech or physically identical noise spectra as the

background stimuli across all competitive conditions eliminates temporal discontinuity and allows isolation of the variable of semantic content. The background-foreground paradigm provides a certain amount of face validity because many real world listening environments contain both background and foreground stimuli.

One reason Carhart and his associates were able to successfully investigate the perceptual masking ability inherent in a speech signal was their specification of noise stimuli that had temporal and spectral characteristics similar to the associated speech stimuli. The spectral characteristics of the broadband noise approximated that of the long term spectrum of the associated speech signal. The temporal characteristics of the speech and noise stimuli were made similar by using the dynamic envelope of the speech to modulate the approximated speech spectrum noise. Although backward running speech also exhibits spectral and amplitude characteristics similar to its foreward running counterpart and its use as a competing message probably reduces perceptual masking secondary to semantic content, it can be argued that such stimuli still contribute semantic content because quasi-intelligible speech components and human voice quality remain imbedded in the stimuli. Also, the resultant inflectional patterns are novel and could create attentional effects. Thus speech modulated noise is a more desirable experimental stimulus.

Speech modulated noise has been used in several other studies (Schroeder, 1968; Horii, House, and Hughes, 1971; Speaks, Wiggington, and Germono, 1971; Katz and Berry, 1971; Berry and Nerbonne, 1971; Chial, 1974), and is especially applicable in the proposed study because (1) it contains no semantic content or verbal attentional

factors; (2) it can be consistently synchronized with its associated input speech signal (Chial, 1973); (3) it can be combined with speech stimuli to produce a foreground-background condition; and (4) the physical spectra, temporal and amplitude characteristics of the speech modulated noise can be made identical to those of its associated input speech signals. The last attribute of the modulated noise stimuli allows equalization of the physical masking spectra of a particular noise stimulus and its associated speech signal input at any given point in time.

PROBLEM STATEMENT

This study sought to examine the effects of competing message semantic content on normal-hearing subject SSI performance while eliminating competing message temporal discontinuity as a variable. For the purposes of this study, semantic content is defined as that characteristic of a competing speech message which contributes varying degrees of meaning. It was expected that semantic content would cause perceptual masking through interference with auditory processing of primary stimuli (synthetic sentences). Perceptual masking is defined as an excess in masking that occurs due to the effect of semantic content. The impact of semantic content was investigated in this study by comparing SSI performance scores for the following competing messages: (1) multi-talker competing message consisting of eight equally intense talkers (MT 8); (2) multi-talker competing message consisting of eight background talkers plus one perceptually prominent foreground talker (MT 8 + 1); (3) dynamic envelope noise competing message derived from the MT 8 competing message (DEN MT);

(4) DEN MT in background plus single-talker in foreground (DEN MT + 1); (5) MT 8 in background with single-talker modulated noise in foreground (MT 8 + DEN 1); and (6) DEN MT in background with DEN 1 in foreground (DEN MT + DEN 1). The six stimuli allow examination of semantic content effect (perceptual masking) in single-ground and foreground-background competing messages. Table 1 reveals the position of semantic content within the respective competing messages.

The most desirable method of assessing SSI performance under the various competing message conditions would be to present all six competing messages to the same group of subjects. This controls for several confounding variables and allows data analyses using an efficient and powerful one-way analysis of variance on repeated measures. However, this experimental paradigm was not possible in the present study. Preliminary testing which involved presentation of synthetic sentences in the presence of six different competing messages at four presentation levels for each competing message (6 x 4 = 24 experimental conditions), indicated a learning effect in regards to the synthetic sentence test items. That is, several subjects were able to correctly identify target synthetic sentences with little or, in some cases, no auditory information. In most instances, the learning effect manifested itself sometime after the 12th experimental condition had been presented. This situation obviously restricted the number of presentations that could be given to a particular subject.

The impact of competing message semantic content was investigated using an experimental design which included several one-way within-subjects and one-way between-subjects analyses of variance in the data

Table 1. Position of Semantic Content within the competing message (background vs. foreground) + = present in stimuli, - = absent in stimuli, 0 = no stimuli.

	Background Semantic Content	Foreground Semantic Content
MT 8 + 1	+	+
MT 8	+	0
DEN MT	-	0
DEN MT + 1	-	+
MT 8 + DEN 1	+	-
DEN MT + DEN 1	-	-

analysis. Three different groups were used to reduce the number of test presentations. Each group was exposed to two different competing messages. Psychometric function slope values and 50% masking efficiency levels were determined from individual subject data. These dependent variables allowed direct comparison of the six different competing messages on SSI performance.

A modified SSI response paradigm was used in this study to reduce variance arising from a small number of test items. The response paradigm is similar to that used by Greenberg (1975). The ten-item message set was discarded in favor of a 25-item four-alternative forced-choice message set. According to Thornton and Raffin (1978), the standard deviation for using a ten-word versus a 25-word list is reduced from 16% to 10% at the 50% correct response level. If the theoretical prediction is correct, use of a 50-item test produces an additional reduction in variance of 3%. This improvement did not appear to justify the increased time and probable subject fatigue that would accompany a 50-item test. Therefore, the subjects task was to correctly identify the stimulus sentence from a set of four alternatives in each of the 25 test presentations.

The following experimental questions were asked:

1. Do mean monaural SSI psychometric function slopes obtained with normal-hearing listeners differ as a function of the presence versus absence of semantic content in a single-ground ipsilateral competing message?

2. Do mean monaural SSI psychometric function slopes obtained with normal-hearing listeners differ as a function of differences in a foreground-background ipsilateral competing message containing semantic content in

   a. background only;

   b. foreground only, and

c. background and foreground?

3. Do mean monaural SSI psychometric function slopes differ as a function of semantic content position and type in a foreground-background ipsilateral competing message?

4. Do mean monaural SSI psychometric function slopes obtained with normal-hearing listeners differ as a function of differences in foreground status in an ipsilateral competing message containing a speech (semantic content) background?

5. Do mean monaural SSI psychometric function slopes obtained with normal-hearing listeners differ as a function of differences in foreground status in an ipsilateral competing message containing a noise background?

6. Do mean monaural SSI 50% masking efficiency levels obtained with normal-hearing listeners differ as a function of the presence versus absence of semantic content in a single-ground ipsilateral competing message?

7. Do mean monaural SSI 50% efficiency levels obtained with normal-hearing listeners differ as a function of differences in a foreground-background ipsilateral competing message containing semantic content in

   a. background only;

   b. foreground only, and

   c. background and foreground?

8. Do mean monaural SSI 50% masking efficiency levels differ as a function of smeantic content position and type in a foreground-background ipsilateral competing message?

9. Do mean monaural SSI 50% masking efficiency levels obtained with normal-hearing listeners differ as a function of differences in foreground status in an ipsilateral competing message containing a speech (semantic content) background?

10. Do mean monaural SSI 50% masking efficiency levels obtained with normal-hearing listeners differ as a function of differences in foreground status in an ipsilateral competing message containing a noise background?

11. How consistent are subject responses within an experimental condition? Are there differences in consistency across experimental conditions?

12. How consistent are subject test-retest SSI performance scores (% correct) for each competing message condition?

CHAPTER II

METHOD

SUBJECTS

Thirty-six normal hearing subjects were selected according to availability from a university student population. Each subject was literate, had normal or corrected vision, and was naive with respect to SSI test material. Normal hearing was defined as pure tone hearing threshold levels (HTLs) at or better than 15 dB (ANSI, S3.6, 1969) for audiometric test frequencies ranging from 250 to 6000 Hz. Spondee hearing threshold levels (obtained using the method proposed by Martin-Stauffer, 1975) were 15 dB or better. Subject speech discrimination scores were 90% or better on the Northwestern University Auditory Test No. 6 presented at a sensation level (SL) of 35 dB (re: the spondee threshold, Tillman and Carhart, 1966). Tympanograms were Type A (Jerger, 1970b) with acoustic reflexes present at normal sound pressure levels (70-100 dB according to Jepson, 1963) at 500, 1000, 2000 and 4000 Hz. All subjects had normal acoustic reflex decay at test frequencies 500 and 1000 Hz. See Appendix A for audiological screening form.

STIMULUS MATERIALS

The study employs two classes of auditory stimuli: primary message and competing message. The primary messages are third-order synthetic sentences. The competing messages include (1) real speech,

(2) speech modulated noise, and (3) speech modulated noise combined with real speech. The following sections will describe the experimental use and discuss the derivation of both classes of stimuli.

Primary Message

Third-order synthetic sentences used in previous studies were found to be inadequate for use in the present experiment. The procedure used in generating these sentential stimuli may have inroduced experimenter bias in the structure of the synthetic sentences because the first two words for each sentence were chosen by the experimenter. Also, generally high variances associated with the most widely known version (Jerger's) suggest possible benefit from increasing the number of test items within a given set and more vigorous control of linguistic, phonetic, and acoustic features of stimuli.

Third-order synthetic sentences were generated using the following procedure. The Thorndike and Lorge (1944) Pool of the 1000 most common words were divided into 16 different lists. Each list was assigned an identification number. The experimenter randomly drew one word from each of two randomly selected lists. The resulting pair formed the "seed" for a synthetic sentence. Three hundred such word-pairs were generated. These, in turn, were divided into thirty sets of ten word pairs each. Five different sets were randomly assigned to each of six graduate students who volunteered to assist in the generation of sentential stimuli. Each volunteer was assigned an identification number (1-6) and a copy of the 16 lists derived from the Thorndike and Lorge pool.

Individuals were seated at separate work stations and instructed in the generation process. Each individual was asked to draw one set of word-pairs from their pool of five sets. For each of the 10 word-pairs on this initial set, the individual randomly selected one of the 16 common word lists and then chose a "third word" from the list that could possibly follow the original word-pair in a meaningful sentence. After each person chose 10 "third words", the first word of each three word sequence was masked and that set of words was exchanged with another individual. The second individual again randomly selected 10 of the 16 common word lists, chose an appropriate "third word" for each of the ten word-pairs, masked the first word of the three word sequence for all ten items, and then randomly exchanged sets. This process continued until all 30 sets had ten synthetic sentences comprised of at least nine words each. The original word-pair used as a "seed" was then eliminated from each synthetic sentence. This was done to minimize possible experimenter bias effects.

The 300 synthetic sentences were then recorded on note cards and examined to verify that

(1) each sentence contained seven words, each of which must have come from the Thorndike and Lorge pool, and

(2) no sentence contained repetition of words.

Synthetic sentences meeting these criteria (N = 300) were then reviewed by a panel of three judges. Each judge independently applied the following criteria to each sentence.

(3) Each synthetic sentence must be between eight and ten syllables.

(4) No obvious complete sentence can exist within a particular sequence of words.

(5) No synthetic sentence can contain a sequence of words that is sexually suggestive or scatological in tone.

A total of 104 sentences were judged as acceptable by all three judges. These 104 synthetic sentences were then recorded according to the following procedure.

Recording Synthetic Sentences

The 104 synthetic sentences were recorded by an adult male speaker of General American Dialect. The speaker stood in a sound-treated chamber (I.A.C. Model 402) and read the selected synthetic sentences into a boom-mounted microphone (Electrovoice RE-16) at a mouth-microphone distance of approximately nine inches. The speaker monitored his voice level via earphones and a remotely mounted VU meter. The signal was routed to an audio mixer (Teac Model 2) the output of which was passed to an electronic switch controlled by discrete logicond timing equipment (Coulbourn). The logic and timing system activated a set of cue lamps which informed the talker of recording status (ready, rehearse, record), controlled inter-stimulus interval (7.5 seconds) and activated the electronic switch during record intervals (5 seconds). The output of the switch was routed to one input channel of a multitrack tape recorder (Teac 40-4).

Selection of Target Synthetic Sentences

One goal of stimulus generation was to make sentences as similar to each other as possible. Toward this end, each of the 104 recorded sentences was graphically recorded (B & K Type 2305) to facilitate measurement of amplitude and duration. The graphic level recorder was adjusted to a paper speed of 10 mm/sec and a pen speed of 500 mm/sec.

Sentence duration was estimated by measuring the distance between the points at which the tracing initially and terminally departed from baseline. The range of sentence durations was from 2.1 to 3.4 seconds. The mean was 2.7 seconds and the standard deviation was 0.3 seconds. Sentences were eliminated from further consideration if measured duration differed from the mean by more than 0.1 seconds. Forty sentences met this criterion.

Sentence amplitude also was measured. Here the goal was to assess the number of amplitude peaks (presumably related to vowel segments) occurring relative to a reference level. The reference level was determined by adjusting a 1 KHz calibration tone to produce a convenient display (40 dB) on the graphic level recorder. The 1 KHz calibration tone had been previously recorded at a level which corresponded to frequent peaks of the target synthetic sentences (i.e., 0 on the VU meter). An average decibel value was determined for each stimulus having between five and eight amplitude peaks above the reference line by summing the peak decibel values above the reference level and then dividing by the number of peaks above the reference level in that particular stimulus. Mean decibel, standard deviation, and range values were then computed as being 1.6 dB, 0.5 dB, and 0.6 - 2.5 dB, respectively. Sentences were eliminated whose average decibel values were not within one standard deviation (0.5 dB) of the mean decibel value. A total of 27 sentences satisfied this criterion. Two of these were arbitrarily discarded; the remaining 25 sentences were designated as experimental target sentences.

The 77 sentences that met the first five criteria, but did not meet the final amplitude or duration criteria were retained for use as distractor sentences.

Construction of SSI Test List

In order to maintain equal representation of target sentences across the four alternatives (a, b, c, or d) for each 25 item test list it was necessary to systematically assign target sentences to a particular alphabetical listing for each of the 25 items within a test list. This was accomplished by randomly drawing coins labeled a, b, c, or d, in a consecutive manner. Four target sentences were designated for four successive test items according to the order that was drawn. Three distractor sentences were then combined with each target sentence for each of the four test items according to the following criteria:

(1) no two synthetic sentences in a given set of four can begin with the same word or phoneme, and

(2) no two synthetic sentences in a given set of four can end with the same word or phoneme.

If any of the three distractor sentences chosen for a specific test item caused the above criteria not to be met, it was returned to the pool and an alternative distractor sentence was chosen. This procedure was repeated until one target sentence and three distractor sentences were chosen for each of the 25 items in all eight SSI test lists. See Appendix B for SSI test lists.

Re-Recording the Target Synthetic Sentences

Following construction of the eight SSI test lists, it was possible to generate the eight experimental tapes. Each experimental tape replicates the order of target sentences contained in its corresponding test list. Before the eight experimental cassette tapes could be produced, it was necessary to record a submaster

reel-to-reel tape that contained only the 25 target synthetic sentences and a 1000 KHz calibration tone. This was accomplished using the following procedure.

The stimuli from the master SSI tape (104 synthetic sentences) were reproduced by one reel-to-reel tape player (Teac 2300-S) and routed to an audio mixer equipped with earphones with auditory monitoring of the stimuli. The output of the audio mixer was connected to a second reel-to-reel tape player (Teac 40-4) that was equipped with pause control to record only selected stimuli. The first tape player was started and allowed to reproduce the entire 104 synthetic sentences, which were constantly being monitored auditorally. The pause control of the second tape player was disengaged at the commencement of an interstimulus interval occurring in front of a target synthetic sentence and re-engaged immediately after the target synthetic sentence had been recorded. This procedure was repeated until all 25 target synthetic sentences and their respective interstimulus intervals were recorded.

The 25 target synthetic sentences on the newly recorded submaster tape were then reproduced in turn and delivered to an audio mixer equipped with earphones for auditory monitoring. Each time a synthetic sentence occurred on the tape, the tape recorder was stopped and a cue switch engaged. The tape was hand-turned to locate the beginning and end of a synthetic sentence. The sentence was then cut out of the submaster tape and inserted between two pieces of 70 inch leader tape. This procedure was repeated until all 25 target sentences were removed from the submaster tape and connected by

leader tape. Seventy inch leader tape was used to insure against print-through during storage.

Following insertion of the sentences between leader tape, all sentences were routed to a graphic level recorder (B & K 2305) and the amplitude measurements discussed above were repeated. The 25 target synthetic sentences were found to have a mean decibel value of +2.38 dB re: the 1 KHz calibration tone with standard deviation and range values of 0.5 dB and 1.5 - 3.4 dB respectively. The calibration tone was subsequently re-recorded at a level 2 dB above the initial level. A recheck of amplitude revealed mean, standard deviation, and range values of +0.14 dB, 0.47 dB, and -0.5 - 1.0 dB respectively.

Generation of the Experimental Tapes

Eight different cassette tapes, each containing a specific order of synthetic sentences separated by interstimulus intervals of approximately 7.5 seconds, were generated for experimental use according to the following procedure. The 25 target sentences and the 1000 Hz calibration tone were reproduced on a reel-to-reel tape player (Teac 40-4) routed through an audio mixer and selectively delivered to a cassette tape player (JVC KD-15). The 1000 Hz calibration tone was adjusted to 0 VU on both the audio mixer and cassette VU meters. The calibration tone was recorded at the beginning of each of the eight cassette tapes. The order in which the synthetic sentences were recorded on each cassette tape was dictated by the corresponding test list (a - h). Each synthetic sentence in a particular list was located on the reel-to-reel tape

recorder. The recorder was then rewound to the beginning of the 70 inch leader tape that preceded the target sentence. The tape was then hand-turned until the approximate leader tape timing mark was directly under the playback head to create the desired interstimulus interval (approximately 7.5 seconds). Both tape players were started simultaneously and allowed to run through the 7.5 second interstimulus interval and duration of the selected synthetic sentence (i.e., approximately 10 seconds). The cassette tape recorder was shut off immediately following the cessation of auditory stimuli (i.e., end of target synthetic sentence). Each of the eight lists was then recorded on the graphic level recorder and the interstimulus intervals between the sentences were measured.

One of the eight experimental tapes was selected (randomly) and graphic level measurements of interstimulus interval durations and amplitude were made for each of the 25 target sentences. In addition, three sentences were randomly selected from the set of 25 targets. Graphic level records were made of each of these three sentences as they occurred on each of the eight experimental tapes. Results of the interstimulus interval and amplitude measurements are shown in Tables 2 and 3 respectively. These results suggest a high degree of success in attempts to produce consistent stimuli.

Competing Messages

The competing messages used in this study are real speech, speech modulated noise, and combination stimuli (real speech plus speech modulated noise). The real speech and speech modulated noise stimuli were devised to examine the amount of perceptual masking effect secondary to the semantic content inherent in the real speech while

Table 2. Mean, standard deviation, and range values of synthetic sentence interstimulus intervals (expressed in seconds).

	A	B	C	D	E	F	G	H
Mean ISI (in seconds)	7.96	7.84	7.7	7.8	7.8	7.7	7.7	7.7
Standard Deviation	0.15	0.12	0.14	0.43	0.12	0.13	0.13	0.15
Range	7.7-8.4	7.5-8.1	7.6-9.8	7.6-9.8	7.5-8.0	7.5-8.0	7.5-8.0	7.4-8.1

Table 3. Mean, standard deviation, and range values of stimuli level re 1 kHz calibration tone for List D and three sentences from each of eight lists.

	LIST D	SENTENCE A	SENTENCE B	SENTENCE C
Mean dB value (re: 1 kHz calibration tone)	0.56	0.85	0.58	0.48
Standard Deviation	0.5	0.36	0.21	0.16
Range	-0.2-1.4	0.5-1.37	0.33-1.0	0.37-0.88

controlling for amplitude, spectral, and temporal factors. The combination stimuli allows examination of the effect of semantic content position (foreground versus background) within a speech/noise stimuli. Each of the competing messages will be discussed in the following sections.

Recording of Competing Speech Messages

Two of the six experimental competing message situations consisted solely of speech material. These were the multi-talker stimulus (MT 8) and the background multi-talker plus a perceptually prominent foreground talker stimulus (MT 8 + 1). It was assumed that these two conditions would contain more semantic content and thus cause more perceptual masking than any of the other experimental conditions with the MT 8 condition causing slightly more perceptual masking than the MT 8 + 1 condition.

The MT 8 stimulus was generated by Chial (1978). Eight General American Dialect talkers (4 females, 4 males) read a passage from a news magazine for approximately five minutes. All talkers were free from disorders of speech and hearing. Each talker stood alone in an audiometric test chamber and spoke into a boom-mounted microphone (Electrovoice RE-16), which was coupled through a mixer (Teac Model 2) to a tape recorder (Nakamichi 700 II). The microphone-to-mouth distance was nine inches. Individual talker tapes were initially mixed onto one of two tapes according to talker gender (second generation). The two tapes were then combined to produce a single 8-talker tape (third generation). Finally, the eight talker tape was re-recorded using splicing techniques to produce a fourth-generation tape of approximately 15 minutes in duration. Care

was taken during the dubbing procedures to maintain equivalent vowel peak levels on all talkers.

Generation of the MT 8 + 1 stimulus was accomplished by mixing a single-talker tape (Chial, 1978) onto the existing MT tape. An adult male with a General American Dialect recorded the single-talker competing message in a "radio broadcast" style. The talker stood alone in a sound-treated chamber and read a passage published in the Reader's Digest into a dynamic microphone (Electrovoice RE-16) which was connected to a cassette tape recorder (Nakamichi 700 II). The talker monitored overall voice level via a remote VU meter and earphones. The single-talker competing message and the multi-talker competing message were remixed according to the procedure described in the following section.

Remixing the Single Talker and Multi-Talker Stimuli

Figure 1 presents a block diagram of the equipment used to remix the two submaster speech signals (multi-talker 8 and single-talker) to three experimental speech stimuli (multi-talker 8 alone, single-talker alone, and a combination of multi-talker 8 and single-talker, i.e., MT 8 + 1). One recorder (Marantz Model 5020) reproduced the single talker material and another (Nakamichi 700 II) reproduced the mixed and dubbed MT 8 signal. These signals were routed to separate input channels of an audio mixer (Teac Model 2) equipped with a VU-metering system (Teac MB-20). The preamplifier channels of the mixer were adjusted to low-pass the signals at a cutoff frequency of 5 kHz, primarily to reduce residual tape noise. The mixer was adjusted to produce different outputs at three of its

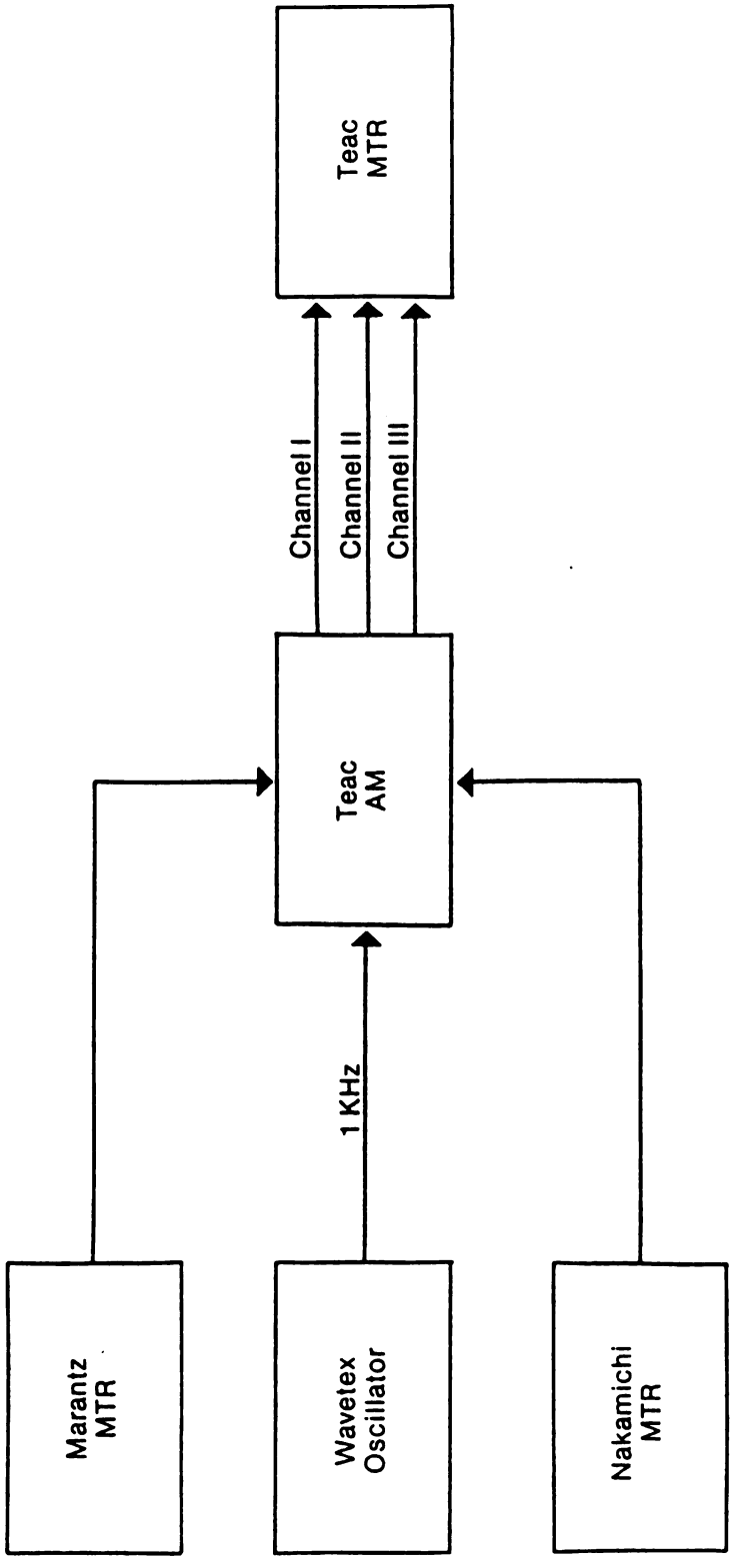

Figure 1. Block diagram of equipment used to remix stimuli

four output ports. One was a "pass-through" version of the single-talker (alone) signal. Another was a "pass-through" version of the multi-talker (alone) signal. The third was a combination of the two. For this combined signal, the average level of the MT 8 component was reduced to approximately 10 dB below the average level of the single-talker component where both were monitored via VU meter. Each of the mixer outputs was then routed to a separate channel of a third tape recorder, (Teac 40-4). The gain controls of the playback machines, the mixer, and the final recorder were adjusted to produce frequent peaks of -1 VU.

Recalibration of Signal Levels

After the experimental stimuli were remixed, but without changing any gain control settings, a level calibration tone (1000 kHz) was recorded on a separate tape segment on each of the three program channels. The level of this tone was monitored via VU meter and was the same for each channel. It was anticipated (and later verified) that the amplitude peaks of the three stimuli would differ in level relative to the calibration tone. Thus, it was necessary to develop a procedure whereby the level of each calibration tone could be adjusted relative to the level of the speech signal associated with that tone.

This was accomplished as follows. Each stimulus was reproduced in turn by the Teac recorder. The output of the recorder was routed through the mixer (Teac Model 2) to a frequency analyzer (B & K 2107) operated as a fast rms linear (20-20 kHz) voltmeter. The output of the voltmeter was graphically recorded (B & K 2305). The level

recorder was adjusted to a pen speed of 500 mm/second and a paper speed of 10 mm/second. For each of the three remixed speech signals, the respective calibration tone and approximately five minutes of the signal was graphically recorded. Fifty successive amplitude peaks were identified at each of two locations (epochs) on the graphic record judged to be representative of the entire record for that stimulus. An amplitude peak was defined as a local maximum which exceeded the immediate adjacent signal level by 2 dB or more. A maximum amplitude was identified above which 10% (N = 5) of the peaks fell. This was done for both measurement epochs, and an average level was computed in decibels relative to the level of the calibration tone. These decibel values constituted a discrepancy in level between the calibration tone and the "10%-peak" level of the stimulus. For the MT 8 signal the mean discrepancy was +4.5 dB, for the single-talker signal +3.5 dB, and for the MT 8 + 1 signal, 3.0 dB.

Calibration signal levels were then modified as follows. The three previously recorded calibration tones were reproduced by a recorder (teac 40-4) and monitored on the mixer VU meters. The reproduced calibration tone levels were set to -5 VU on the mixer. The tape recorder was stopped and a sine wave oscillator signal was routed through the mixer to each of the three output channels. The level of this signal was adjusted independently for each channel to equal -5 VU, plus the respective level discrepancy associated with the particular channel. These adjusted levels were then recorded on a new tape segment which was subsequently spliced to the remixed program tape.

The "10% peak" measurement procedure was repeated to verify the effect of the correction process. For each of the three speech stimuli (MT 8 alone, single-talker alone, and MT 8 + 1) the discrepancy between the level of the adjusted calibration signal and the speech stimulus was less than 1 dB.

Finally, stimuli were reproduced by the Teac reel-to-reel tape player, passed through the audio mixer for level control, and routed to a cassette recorder (Marantz 5020). The MT 8 and MT 8 + 1 stimulus tapes were used during the main experiment while the single-talker tape was used in generating the DEN MT 8 + 1 experimental tape.

Analysis of the Speech Materials

Before generation of the DEN stimuli, each speech stimulus (MT 8, MT 8 + 1, and single-talker) underwent a spectral analysis procedure to define its long-term spectrum. This spectral information was later used in defining the spectral characteristics of the associated DEN stimuli. Figures 2 and 3 describe the instrumentation used in the narrow-band and 1/3 octave spectral analysis procedures respectively. For the narrow-band analysis, each stimulus was reproduced from a different channel of a tape recorder (Teac 40-4). The output of the tape player was adjusted until a 1000 Hz calibration tone produced a reading of 0 VU. The signal was then routed to an audio mixer (Teac Model 2), which was also adjusted to yield a reading of 0 VU. The weighting network of the mixer was not engaged. Next, the stimulus was passed to a narrow-band analyzer (B & K 2031). The input sensitivity of the analyzer was adjusted to produce a convenient

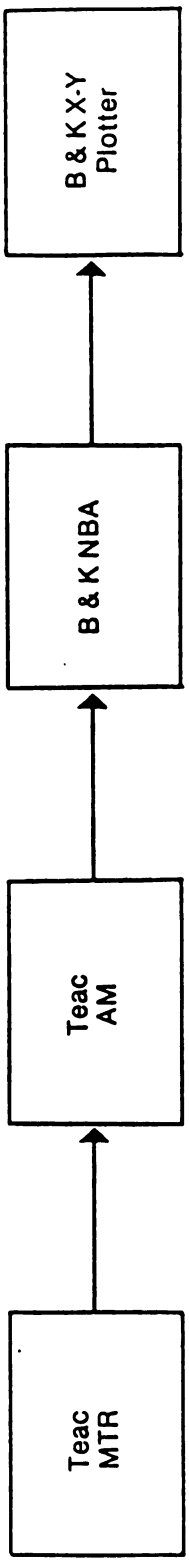

Figure 2. Block diagram of equipment used to perform and record narrow/band analysis

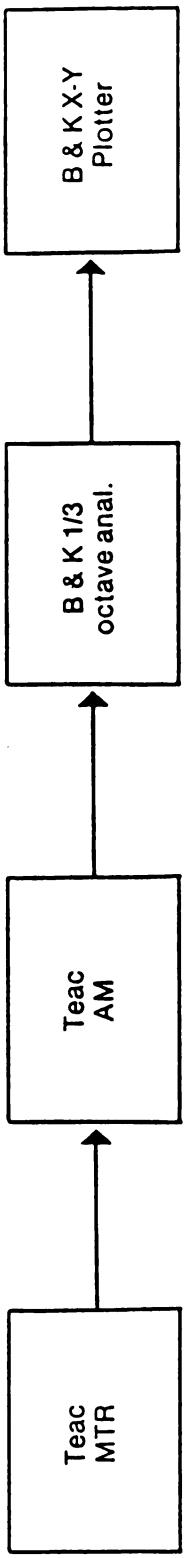

Figure 3. Block diagram of equipment used to perform and 1/3 octave band analysis

overall level deflection and to an arbitrary reference level which also produced a convenient deflection. This was done to allow measurement of the entire dynamic range of the stimulus. A linear average of the 256 samples was obtained at 200 m/sec averaging interval, weighted by a hanning window. The total time elapsed to average 256 samples was approximately 45 seconds. It had earlier been determined that a 45 second averaging time was needed to obtain a steady-state spectrum (one unaffected by duration or number of samples). The average long-term spectra for each stimulus was successively displayed on the analyzer screen and later transferred to an X-Y plotter (B & K 2308) for permanent record.

Following the narrow-band analysis procedure, the stimuli were analyzed using a 1/3 octave band analyzer (B & K 2131). The DEN stimuli were generated using the spectral information obtained with the 1/3 octave band analyzer. Each stimulus was reproduced using a 4-channel tape player (Teac 40-4), which routed the signal to an audio mixer (Teac Model 2) and then to the 1/3 octave band analyzer. The tape player and audio mixer were adjusted to produce a 0 VU reading when the 1 kHz calibration tone was introduced. The 1/3 octave band analyzer was then activated and its sensitivity adjusted until the 1 kHz calibration tone equalled 90 dB (relative). A 64 second averaging interval was selected to approximate the 45 second averaging interval in the narrow-band analysis. The stimuli were then passed in turn to the analyzer and the spectra of each was successively displayed on the analyzer screen. The spectra were later transferred to an X-Y plotter (B & K 2308) for permanent record (see Figures 4, 5, and 6).

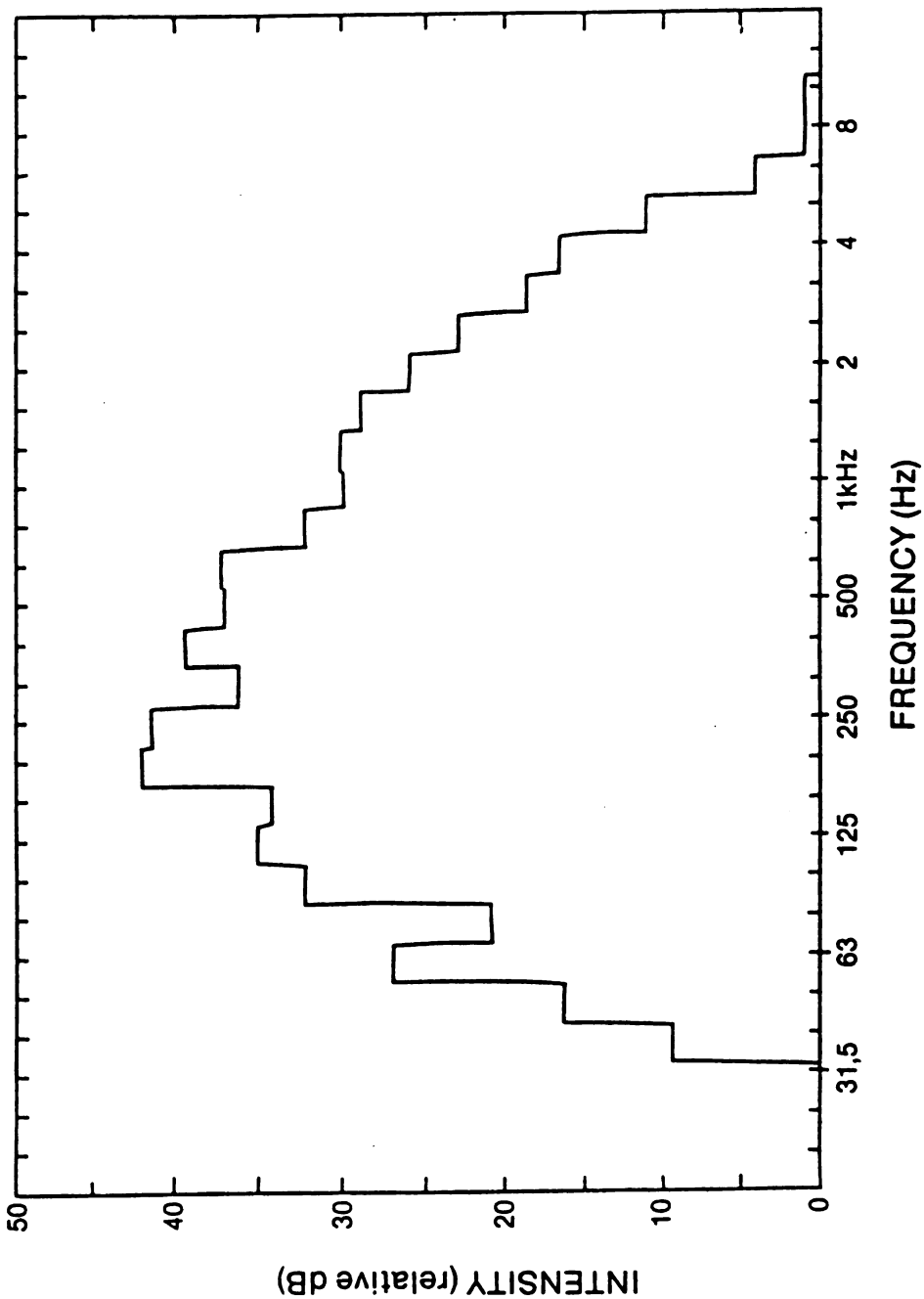

Figure 4. Long-Term Spectrum of MT 8

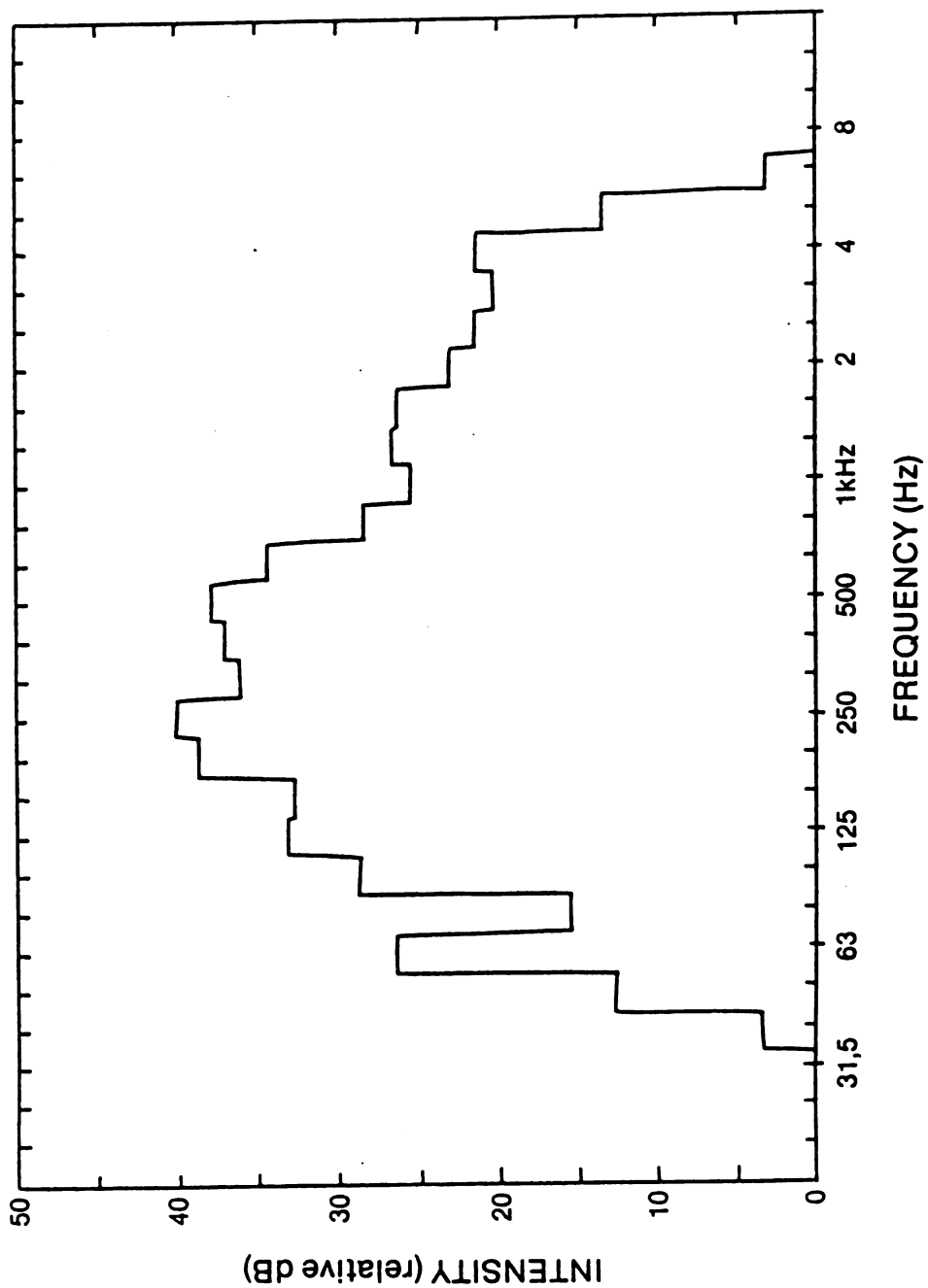

Figure 5. Long-Term Spectrum of MT 8 + 1

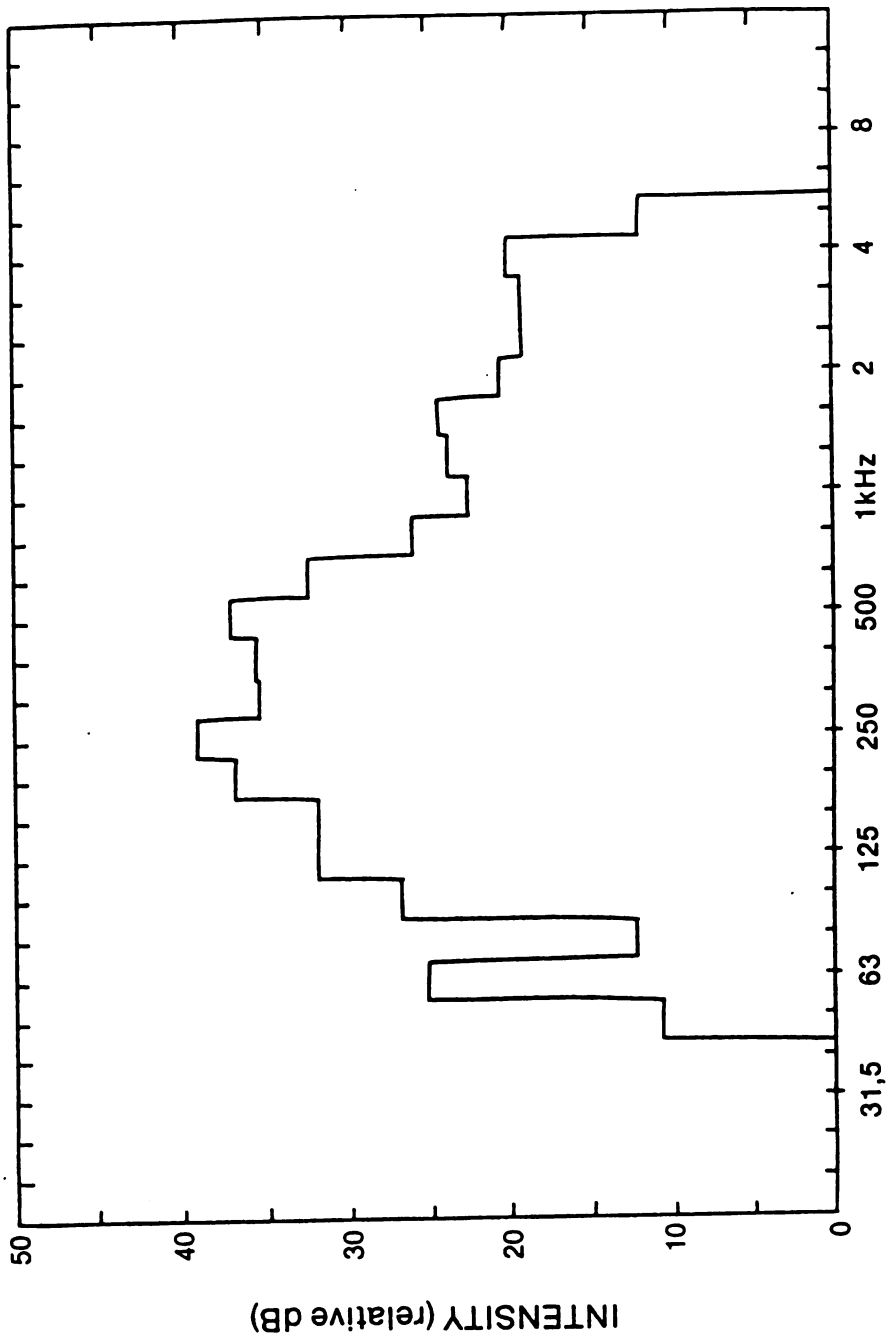

Figure 6. Long-Term Spectrum of Single-Talker

Long Term Spectra Simulation

After spectral analysis of the speech materials, it was possible to generate spectra very similar to the long-term spectra of the particular speech stimulus. This was accomplished by generating white noise (Coulbourn S-81-02) and routing it through an audio mixer (Teac Model 2), which delivered it to the input port of a multifilter (General Radio 1925). The multifilter was preset to shape the input noise spectra in accordance with spectral specifications that had been obtained by the previously described analysis procedure.

Apparatus for Modulating the Speech Spectrum Noise

After the spectral characteristics of each speech stimulus had been identified and simulated, it was possible to modulate the specific speech spectra by the desired speech stimulus. This was accomplished using an instrument designed by Chial (1973). This device has the capability of accepting a broad-band noise input signal (in this case, specified speech noise) and multiplying it by the amplitude envelope of a second input signal (speech). The amplitude envelope is extracted by means of full-wave rectification and subsequent filtering (low-pass at 20 Hz, see Figure 7). According to Horri, House, and Hughes (1971) most of the amplitude variation in a speech waveform occurs at frequencies below 20 Hz. The output of the device (designated CD-1) is the analog product of the instantaneous amplitude of the signal presented to the noise port and the instantaneous amplitude of the waveform envelope extracted from the input speech signal.

Changes in the amplitude of the specifically shaped speech spectra were dictated by changes in the amplitude of the corresponding speech input signal across time. A 30 m/sec lag-time (in this case,

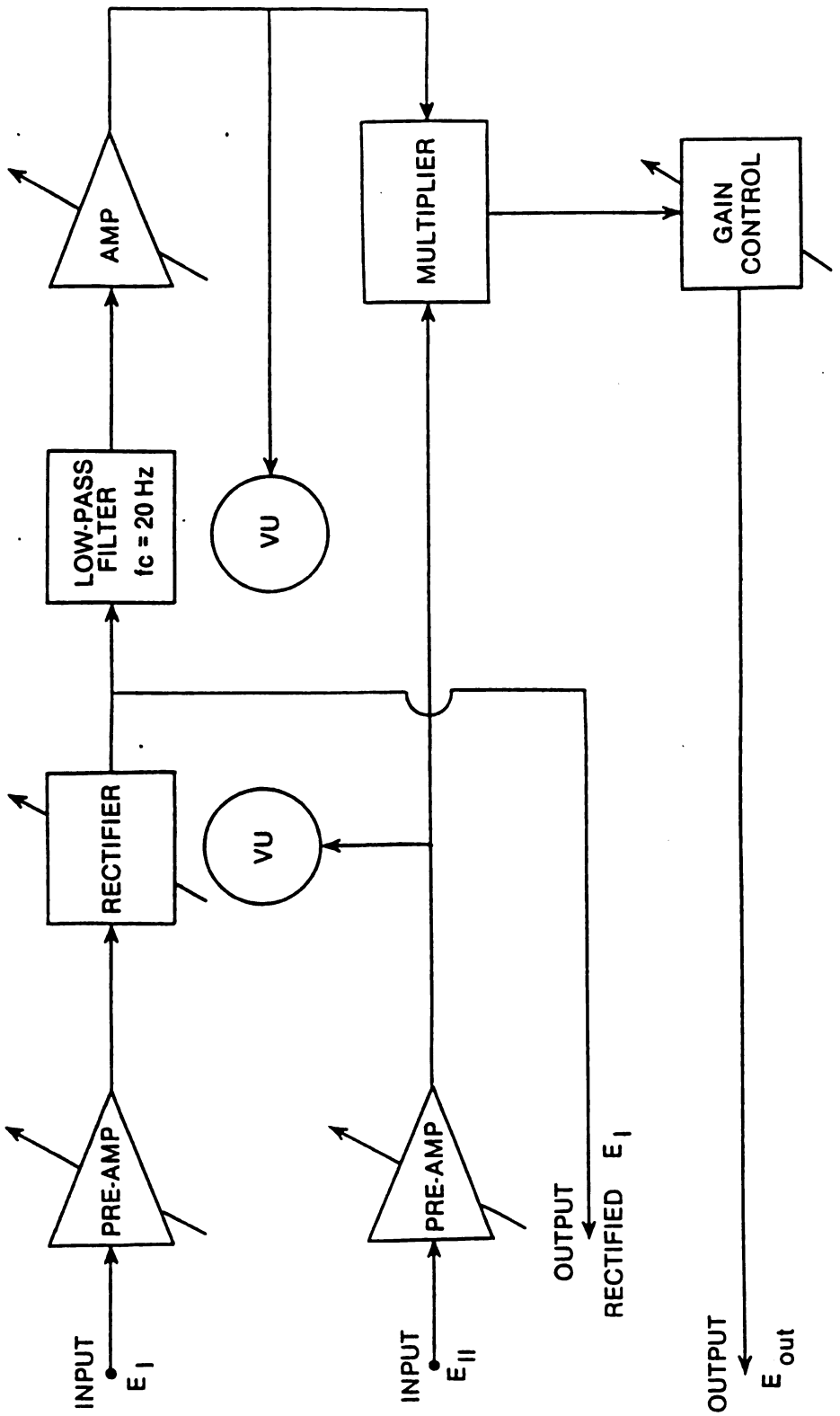

Figure 7. Major components of CD-1

DEN following speech stimuli) secondary to the filtering process has been identified (Horri, House, and Hughes, 1971; Chial, 1973) but is not relevant in the present study.

Generation of DEN Stimuli Competing Message

The goals of the study also require generation of stimuli which retain the amplitude, temporal, and spectral characteristics of specified speech stimuli (MT 8, single-talker, and MT 8 + 1), but were void of semantic content. This was accomplished by modulating a specified speech spectrum noise by the associated speech signal (either MT 8, single-talker, or MT 8 + 1). Each speech modulated noise stimulus (DEN) exhibits acoustical characteristics of speech spectrum noise that has amplitude fluctuations and temporal patterns identical to its real speech stimulus counterpart. Subjectively, the DEN MT sounds like steady state speech noise with slight fluctuations in loudness; the DEN 1 sounds like speech noise that has fluctuations in loudness and noticeable pauses between consecutive noise segments (i.e., words); and the DEN MT + DEN 1 is characterized by steady state speech noise in the background with the DEN 1 in the foreground (-10 dB foreground/background ratio).

Figure 8 depicts the instrumentation used in generating the DEN stimuli. Three different speech stimuli (single-talker, MT 8, and MT 8 + 1) were reproduced by a tape player (Teac 40-4) and routed in turn through an audio mixer (Teac Model 2) to an amplifier (Coulbourn S-82-24) and finally to the speech input channel of the CD-1. The noise input channel of the CD-1 received the associated simulated long-term spectrum produced by the white noise generator (Coulbourn S-81-02) and multi-filter. The input preamplifiers of the CD-1 were

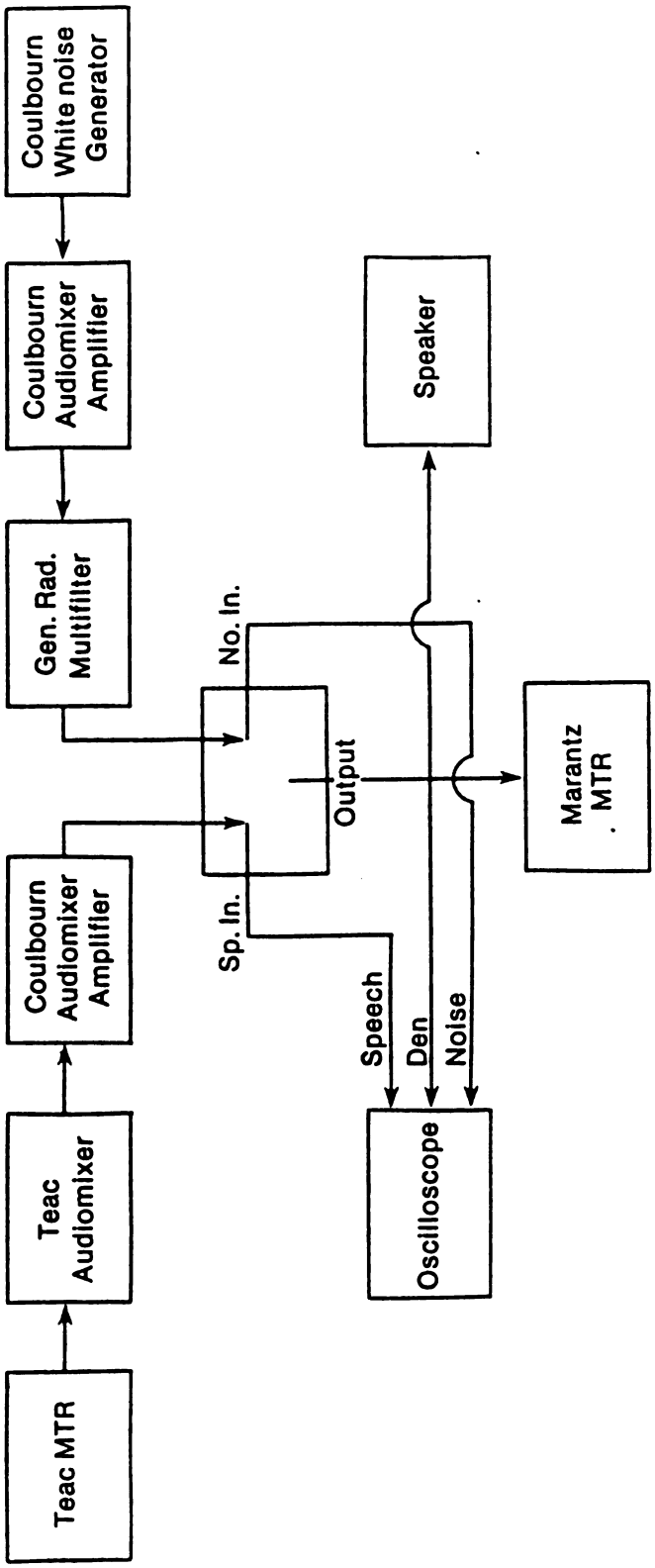

Figure 8. Block diagram of equipment used to generate DEN stimuli

adjusted to levels previously determined to produce the greatest dynamic range (about 45 dB) in the input signal. The amplitude modulated output signal was recorded by means of a cassette recorder (Marantz Model 5020). The two input signals and the output signal were monitored with an amplifier-loudspeaker system and an oscilloscope.

Recording Calibration Tones for DEN Stimuli

Following the initial recording of the DEN stimulus, each stimulus was reproduced by a cassette tape player (Marantz Model 5020) through an audio mixer and routed to a multi-track recorder (Teac 40-4). The level of each DEN stimulus was set to produce frequent peaks of approximately 0 VU. A 1 kHz calibration tone, 60 seconds in duration, was recorded in front of each DEN stimulus on the reel-to-reel tape. The calibration tone was generated by a wavetex oscillator (Model 182) and routed through the audio mixer before being passed to the Teac tape player. The level of each calibration tone was adjusted to approximate the VU deflection of their associated DEN stimulus(0 VU). All three DEN stimuli and their associated calibration tones were then passed in turn from the tape player through the audio mixer and a frequency analyzer operating as an RMS voltmeter (B & K 2107) to a graphic level recorder (B & K 2305) for visual inspection and computation of the respective levels. An adjustment in calibration tone levels was made for each stimulus using the "10% peak" method discussed previously.

Finally, the stimuli and their associated calibration tones were passed from the reel-to-reel recorder through the audio mixer

(calibration tone set at 0 VU) and recorded on a cassette tape recorder (Marantz 5020). The DEN MT and the DEN MT + 1 tapes were used as experimental tapes, while the DEN 1 tape was used in generation of the MT 8 + DEN 1 experimental tape.

Generation of Combination Stimuli (DEN + Real Speech)

Another goal of this study is to compare perceptual masking effects of two temporally continuous stimuli opposing each other in background versus foreground semantic content position. The DEN MT + 1 and MT 8 + DEN 1 stimuli allow this comparison. The DEN MT + 1 stimulus contains semantic content in the foreground (+10 dB S/N), but not in the background. The MT 8 + DEN 1 exhibits semantic content in the background (-10 dB S/N), but not in the foreground. The two stimuli are identical in amplitude, temporal, and spectral characteristics and each contains semantic content. Thus, it is reasoned that any difference in perceptual masking efficiency must be related to the positioning of semantic content within the background-foreground dichotomy.

Subjectively, the DEN MT + 1 stimulus is characterized by a single-talker being heard approximately 10 dB above a fairly steady-state speech noise. The MT 8 + DEN 1 is characterized by multi-talker speech babble in the background and a louder (+10 dB) yet fluctuating speech noise in the foreground. The audibility of speech is greater in the DEN MT + 1 stimulus, but more continuous in the MT 8 + DEN 1 stimulus.

Generation of the combination stimuli involved a two-step procedure. First, the MT 8 and DEN 1 stimuli were reproduced by two

different cassette recorders (JVC KD-15 and Marantz 5020 respectively). These signals were routed to separate channels of an audiomixer (Teac Model 2) with the calibration tone of the DEN 1 adjusted to 0 VU and the MT 8 calibration tone adjusted to -10 VU. The stimuli were mixed and delivered to one channel of a reel-to-reel recorder (Teac 40-4). Second, the newly generated combination stimulus (MT 8 + DEN 1) was reproduced by the reel-to-reel recorder, routed through the audiomixer, and delivered to the JVC cassette recorder. Generation of the DEN MT + 1 followed the same procedure with the single-talker stimulus being adjusted to +10 dB re the DEN MT stimulus.

After both combination stimuli were recorded on cassette tapes, they were passed to the graphic level recorder to determine stimulus levels. Using the "10% peak" procedure discussed previously, it was determined that both stimulu were approximately +2.5 dB re their respective calibration tones. An adjustment in calibration tone level was made for each stimuli and subsequently verified.

EXPERIMENTAL APPARATUS

Primary message SSI stimuli were reproduced on one tape player (JVC KD-15) and the competing messages were reproduced on another tape player (JVC KD-15). The primary and competing messages were routed to separate channels of a speech audiometer (Grason-Stadler Model 162). The primary signal was also connected to logic devices which activated a cue lamp each time a target sentence was presented. A voltmeter connected to the output of the audiometer monitored output signal level delivered to a test earphone (TDH-49 with MX-41/AR cushion)

mounted with a TC-89 headband. A dummy earphone and cushion was placed over the non-test ear. A block diagram of the experimental apparatus is shown in Figure 9.

EXPERIMENTAL PROCEDURES

Following the informed consent (see Appendix C), screening procedures, and group assignment subjects were seated in a sound-booth and read standardized instructions (see Appendix D) by the experimenter. The experimental events are sequenced in Figure 10.

The initial portion of the experimental session was devoted to practice. Five non-experimental synthetic sentences were presented to the test ear at a 40 dB sensation level (SL) in quiet to familiarize the subject with the four-alternative forced-choice paradigm. Eighteen other non-experimental synthetic sentences were presented at 40 dB SL with the competing stimuli adjusted to obtain a -2 dB signal-to-noise ratio to provide the subjects with nine listening experiences with each of two competing message conditions according to group assignment. Each of the three subject groups received one of the following pairs of competing message conditions:

(1) DEN MT and MT 8
(2) MT 8 + 1 and DEN MT + DEN 1
(3) MT 8 + DEN 1 and DEN MT + 1

The subjects task was to circle the correct item on the response sheet. Subjects had to score 100% on the practice test to participate in the main experiment. The practice test is displayed in Appendix E.

Following the practice session, each subject received eight experimental conditions and two test-retest conditions during a one hour

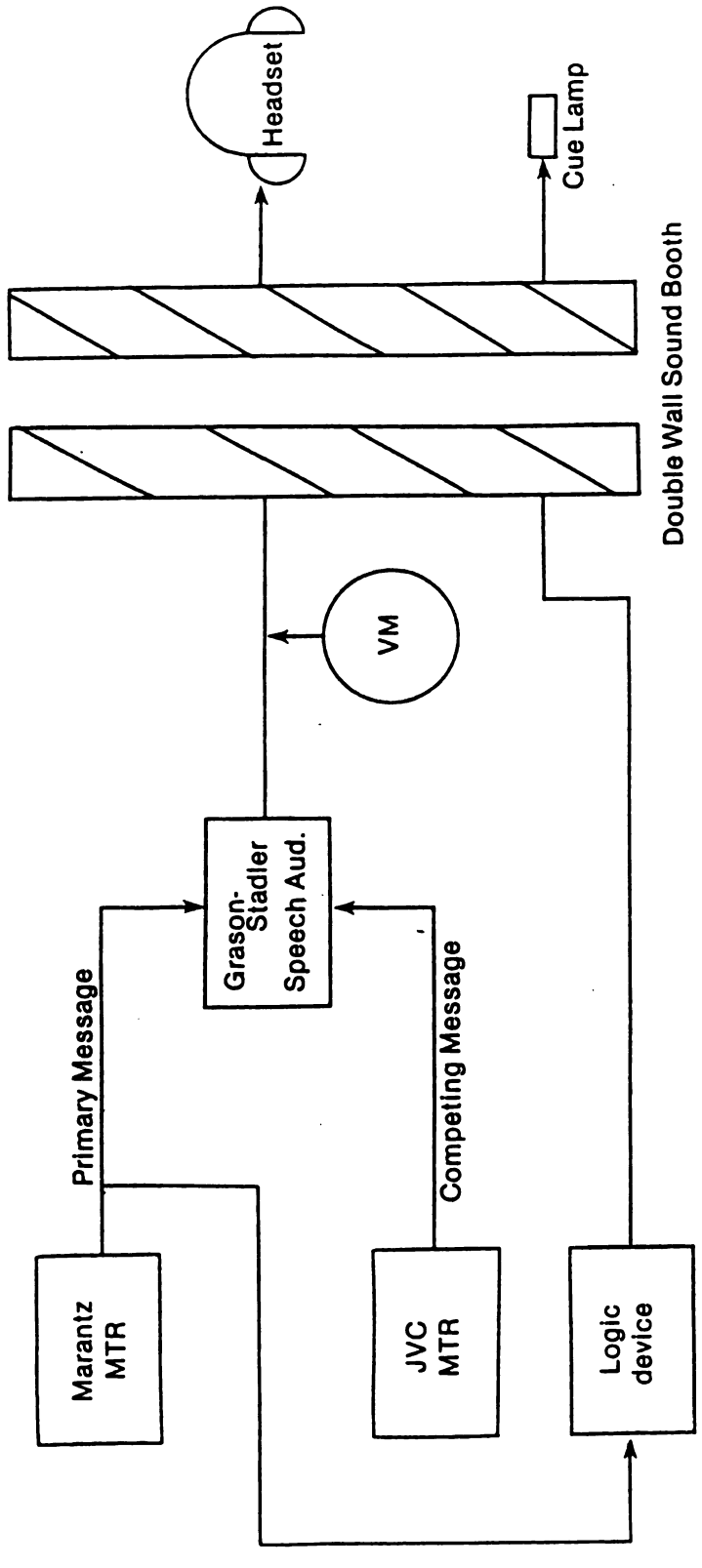

Figure 9. Experimental apparatus

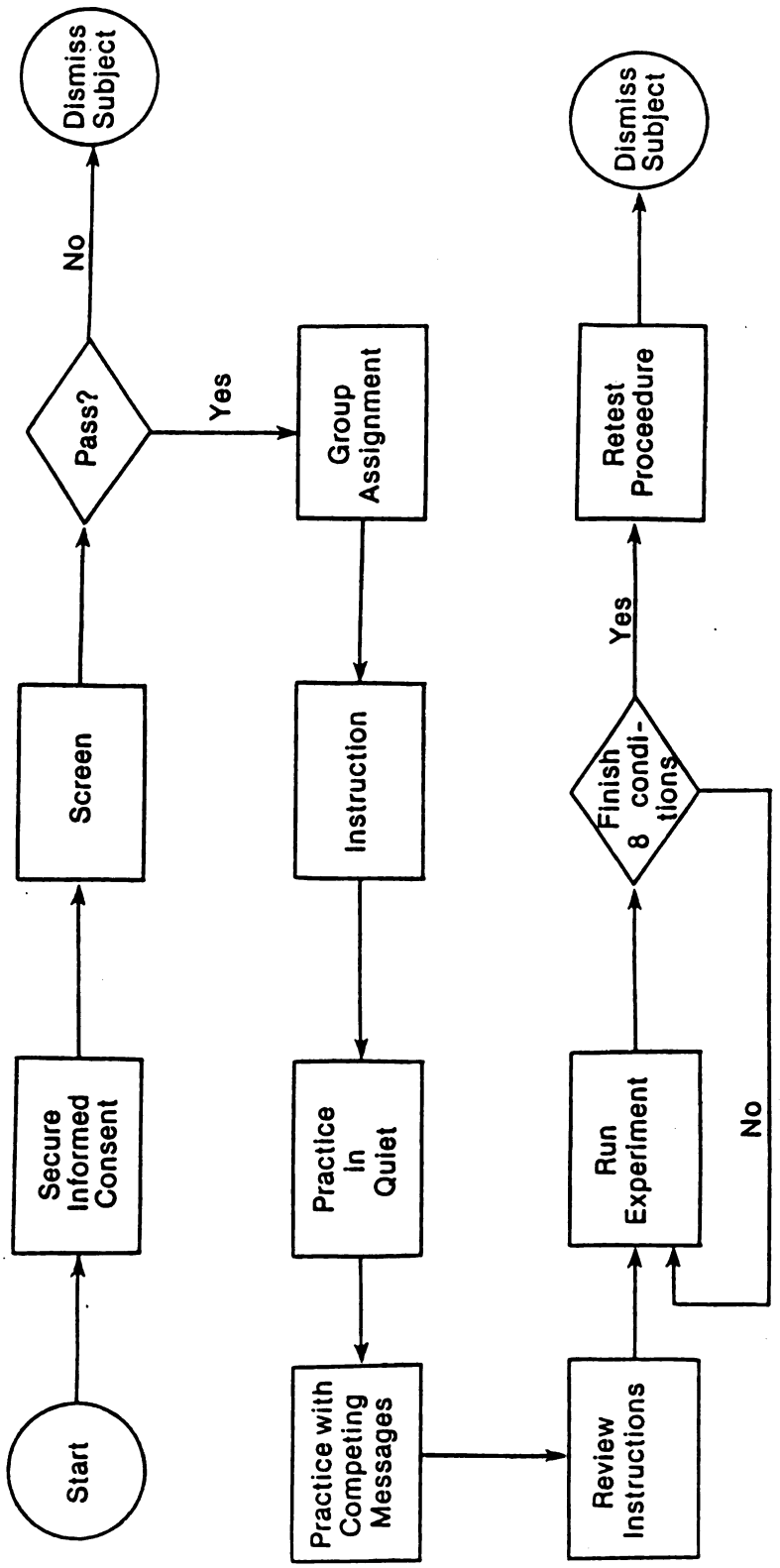

Figure 10. Block diagram of experimental events for Session I

testing session. Each of the eight experimental conditions consisted of a 25-item test list presented at one of four MCRs for one of two competing messages. Test-retest data were collected at the MCR value which yielded the nearest to 50% correct score. The MCR values were -14, -12, -10, and -8 dB for the MT 8 and MT 8 + 1 competing messages; -18, -16, -14, and -12 dB for the DEN MT competing message; -20, -18, -16, and -14 dB for the MT 8 + DEN 1 competing message; and -22, -20, -18, and -16 dB for the DEN MT + 1 and DEN MT + DEN 1 competing messages. MCR values for the competing messages were determined in a pilot study (see Appendix F for pilot study). The synthetic sentences were presented at 40 dB SL and the SPL of the competing message was varied to obtain the desired MCR. A cue lamp alerted the subject to the presentation of each target sentence. The subjects task was to listen to each presentation and circle the correct item on the answer sheet. The orders of MCR and list presentation for a particular competing message were both randomized for each subject. The competing messages were presented in a counter-balanced order. Appendix G reveals the test protocol.

During preliminary testing, it was noted that for some competing message conditions a particular subject may have scored (1) entirely below 60%, (2) entirely above 40%, or (3) entirely between 44% and 56% across the MCR values. This phenomenon was probably related to the small 2 dB step size between adjacent MCR values coupled with the steep psychometric function slope, which together are extremely sensitive to variations in subject performance. The problems this situation created were (1) artifactual slopes and (2) inability to compute 50% masking efficiency levels. These problems were solved by

implementing a rule that stated a given subject must score above 60% and below 40% for each competing message condition. If this rule was not met with four MCR values, additional MCR values were presented. Performance at all MCR values were used in computing psychometric function slope and 50% masking efficiency levels.

CHAPTER III

RESULTS

INTRODUCTION

This study was conducted to determine the effect of ipsilateral competing message semantic content on normal-hearing listener SSI performance. Thirty-six normal-hearing subjects were chosen from a university population and equally divided into three experimental groups.

SSI performance was evaluated using two different competing messages for each of three experimental groups. The two competing messages for each experimental group were designed to investigate a particular aspect of semantic content effect. Group I subjects received competing messages designated MT 8 + DEN 1 and DEN MT + 1. These were similar in temporal, amplitude, and spectral chacteristics, but differed in the position and type of semantic content within a foreground-background competing message. Group II subjects heard competing messages MT 8 and DEN MT. These competitors allowed examination of the effect of the presence versus absence of semantic content in a single-ground competing message while holding constant temporal, amplitude, and spectral characteristics. Group III subjects were exposed to competing messages MT 8 + 1 and DEN MT + DEN 1. Again, the competitors were similar in temporal, amplitude, and spectral characteristics but differed in the presence versus absence of semantic content in both grounds of a foreground-background competing

message. That is, the MT 8 + 1 competing message had semantic content in both foreground and background while the DEN MT + DEN 1 competing message had no semantic content in either foreground or background.

Each subject received an audiological screening to ensure bilaterally normal hearing, middle ear function, and acoustic reflexes. The initial part of the experimental session was devoted to practice. Each subject listened to synthetic sentences presented in quiet and in the presence of their respective competing messages to familiarize them with the experimental task. Each subject then listened to 25-item test list presented at four MCRs for both competing message conditions, (i.e., a total of eight experimental conditions).

Psychometric functions were plotted for each subject. The dependent variables of psychometric function slope values and 50% masking efficiency levels were derived from individual subject psychometric functions for each competing message via the method of least squares. The 50% masking efficiency levels were interpolated from individual psychometric functions and represent the message-to-competition ratio at which 50% correct performance should be achieved.

Test-retest reliability information was collected for each competing message at the MCR value which produced the closest to 50% correct score. Retest data were gathered immediately following the experimental procedure.

The following experimental questions were asked:

1. Do mean monaural SSI psychometric function slopes obtained with normal-hearing listeners differ as a function of the presence versus absence of semantic content in a single-ground ipsilateral competing message?

2. Do mean monaural SSI psychometric function slopes obtained with normal-hearing listeners differ as a function of differences in a foreground-background ipsilateral competing

competing message containing semantic content in

a. background only;

b. foreground only, and

c. background and foreground?

3. Do mean monaural SSI psychometric function slopes differ as a function of semantic content position and type in a foreground-background ipsilateral competing message?

4. Do mean monaural SSI psychometric function slopes obtained with normal-hearing listeners differ as a function of differences in foreground status in an ipsilateral competing message containing a speech (semantic content) background?

5. Do mean monaural SSI psychometric function slopes obtained with normal-hearing listeners differ as a function of differences in foreground status in an ipsilateral competing message containing a noise background?

6. Do mean monaural SSI 50% masking efficiency levels obtained with normal-hearing listeners differ as a function of the presence versus absence of semantic content in a single-ground ipsilateral competing message?

7. Do mean monaural SSI 50% efficiency levels obtained with normal-hearing listeners differ as a function of differences in a foreground-background ipsilateral competing message containing semantic content in

a. background only;

b. foreground only, and

c. background and foreground?

8. Do mean monaural SSI 50% masking efficiency levels differ as a function of semantic content position and type in a foreground-background ipsilateral competing message?

9. Do mean monaural SSI 50% masking efficiency levels obtained with normal-hearing listeners differ as a function of differences in foreground status in an ipsilateral competing message containing a speech (semantic content) background?

10. Do mean monaural SSI 50% masking efficiency levels obtained with normal-hearing listeners differ as a function of differences in foreground status in an ipsilateral competing message containing a noise background?

11. How consistent are subject responses within an experimental condition? Are there differences in consistency across experimental conditions?

12. How consistent are subject test-retest SSI performance scores (% correct) for each competing message condition?

DATA REDUCTION

Subject performance was indexed by percent-correct scores at each MCR for each competing message (see Appendix H). Subjects who did not score either below 44% or above 56% using the four experimental MCRs were tested at additional MCRs until this criterion was met. Psychometric function slope values and 50% masking efficiency levels were derived for each subject from their respective psychometric functions using a linear regression equation. These derived dependent variables allowed direct comparison of the effect of the various competing messages on SSI performance.

STATISTICAL PROCEDURES

Group means, standard deviations, and ranges were computed for each experimental condition (6 competing message conditions x 4 MCRs = 24 experimental conditions). Mean psychometric functions were plotted for each of the six competing message conditions. Group means, standard deviations, and ranges for the derived dependent variables of psychometric function slope values and 50% masking efficiency levels were then determined for each competing message condition.

Reliability Procedures for SSI Data

Reliability of measurement was assessed through three statistical procedures. Consistency of response within administrations of the

SSI test was indexed by odd-even reliability computations; consistency across administrations was reflected by test-retest reliability computations; and consistency within experimental conditions was indexed via the standard error of the mean.

Odd-Even Reliability. The intra-list odd versus even reliability data were obtained by determining the percent-correct of odd-even test items for each list at each MCR for all competing message conditions. These data estimate reliability within each test administration. Also, the Spearman-Brown formula was used to correct the odd-even coefficient for the lesser number of items used in calculating the coefficient.

Test-Retest Reliability. Test-retest data were obtained at the MCR value which yielded the closest to 50% correct score for each subject across both competing message conditions. These data permit assessment of test stability (reliability) across successive administrations.

Standard Error of the Mean. The standard error of the mean indicates the "normalized" dispersion of a group of scores and is defined as:

$$SEM = \frac{SD}{\sqrt{N}}$$

The resulting value estimates the amount of precision or degree of accuracy with which the SSI measurements can be made. A small sample standard deviation will yield a small standard error of the mean; in turn, a small standard error of the mean reflects good precision, minimal variability, and (presumably) good reliability.

Analysis of SSI Data

Analysis of both dependent variables (psychometric function

slope values and 50% masking efficiency levels) for each of the three groups followed a one-way within-subject analysis of variance (ANOVA) with repeated measures on the two competing messages (Linton and Gallo, pp. 166-174, 1975). Analysis of the respective dependent variables across subject groups was accomplished using one-way between-subject ANOVA's (Linton and Gallo, pp. 138-144, 1975). Strength of association measures were computed for ANOVA's exhibiting significant F-ratios at the .05 level. The strength of association measures, ETA squared (η^2) for the within-subject ANOVA's and OMEGA squared (ω^2) for the between-subject ANOVA's, estimate the proportion of variance in the dependent variables accounted for by the independent variables. Tukey's test of specific comparisons was used to assess the significance of mean differences for ANOVA's with three levels of the independent variable (Linton and Gallo, pp. 316-319, 1975).

Description

Tables 4, 5, and 6 summarize mean percent-correct, standard deviations, and ranges of performance as a function of MCR across paired competing messages for subjects in groups I, II, and III respectively. Subject performance fell with each decrease in MCR for all competing messages except the DEN MT competing message. Mean percent-correct scores for this competing message were equivalent at the -16 dB and -18 dB MCRs (approximately 35%). A reduction in performance apparently did not occur when the MCR was decreased from -16 dB to -18 dB because performance at the -16 dB MCR already reflected the lowest point on the psychometric function. Also, performance at the least negative MCR value (-12 dB) for the DEN MT competing message,

Table 4. Mean percent-correct scores, standard deviations, and ranges of Group I subjects for competing messages MT 8 + DEN 1 and DEN MT + 1 as a function of message-to-competition ratio (N = 12).

COMPETING MESSAGE	PERCENT CORRECT MEAN	S.D.	RANGE
MT 8 + DEN 1			
MCR			
- 14	78.3	12.1	36
- 16	60	8.6	24
- 18	47.6	12.5	40
- 20	35.6	7.5	32
DEN MT + 1			
MCR			
- 16	75.3	11.4	40
- 18	62.3	15.7	44
- 20	43	13.3	32
- 22	33	10.9	36

Table 5. Mean percent correct scores, standard deviations, and ranges of Group II subjects for competing messages MT 8 and DEN MT as a function of message-to-competition ratio (N = 12).

COMPETING MESSAGE	PERCENT CORRECT MEAN	S.D.	RANGE
MT 8			
MCR			
- 8	80.6	9.9	28
- 10	58.6	14.3	40
- 12	47.6	11.9	36
- 14	28	5.9	20
DEN MT			
MCR			
- 12	63.3	8.4	36
- 14	52	10.6	36
- 16	35	7.2	24
- 10	35	8.2	24

Table 6. Mean percent correct scores, standard deviations, and ranges of Group III subjects for competing messages MT 8 + 1 and DEN MT + 1 as a function of message-to-competition ratio (N = 12).

COMPETING MESSAGE	PERCENT CORRECT MEAN	S.D.	RANGE
MT 8 + 1			
MCR			
- 8	80	7.6	20
- 10	61.6	13.2	40
- 12	44.6	11.7	32
- 14	33.6	10.5	36
DEN MT + DEN 1			
MCR			
- 16	82	10.8	28
- 18	70	5.7	20
- 20	49.3	9.9	32
- 22	41.3	10.6	32

yielded a mean score significantly less than corresponding MCRs of the other competing messages. These findings suggest the MCRs selected for the DEN MT competing message should have ranged from -16 dB to -10 dB to include a more complete portion of the psychometric function.

Figures 11 through 16 separately illustrate psychometric functions for the six competing message conditions. Each datum represents mean percent-correct scores across 12 subjects. Standard deviations ($\pm$ 1 standard deviation) also are displayed. The figures show the linear portion of the psychometric function was bracketed for each of the various competing messages. The relations among the six competing messages are compared in Figure 17. Although the psychometric function slopes of the six competing message psychometric functions appear similar, there is a noticeable difference in masking efficiency. More efficient maskers are shifted horizontally toward the right-hand side of the figure. The most efficient maskers are the MT 8 and MT 8 + 1 competing messages. The DEN MT competing message exhibits an intermediate degree of masking efficiency while the MT 8 + DEN 1, DEN MT + 1, and DEN MT + DEN 1 competing messages are less efficient.

Table 7 and Figure 18 summarize psychometric function slope means, standard deviations, and ranges for competing messages within subject groups. Because of the configuration of the mean DEN MT psychometric function, individual subject psychometric function slopes were computed using three data points (-16, -14, and -12 dB) from the linear portion of the psychometric function.

The steepness of the psychometric function slope indicates how

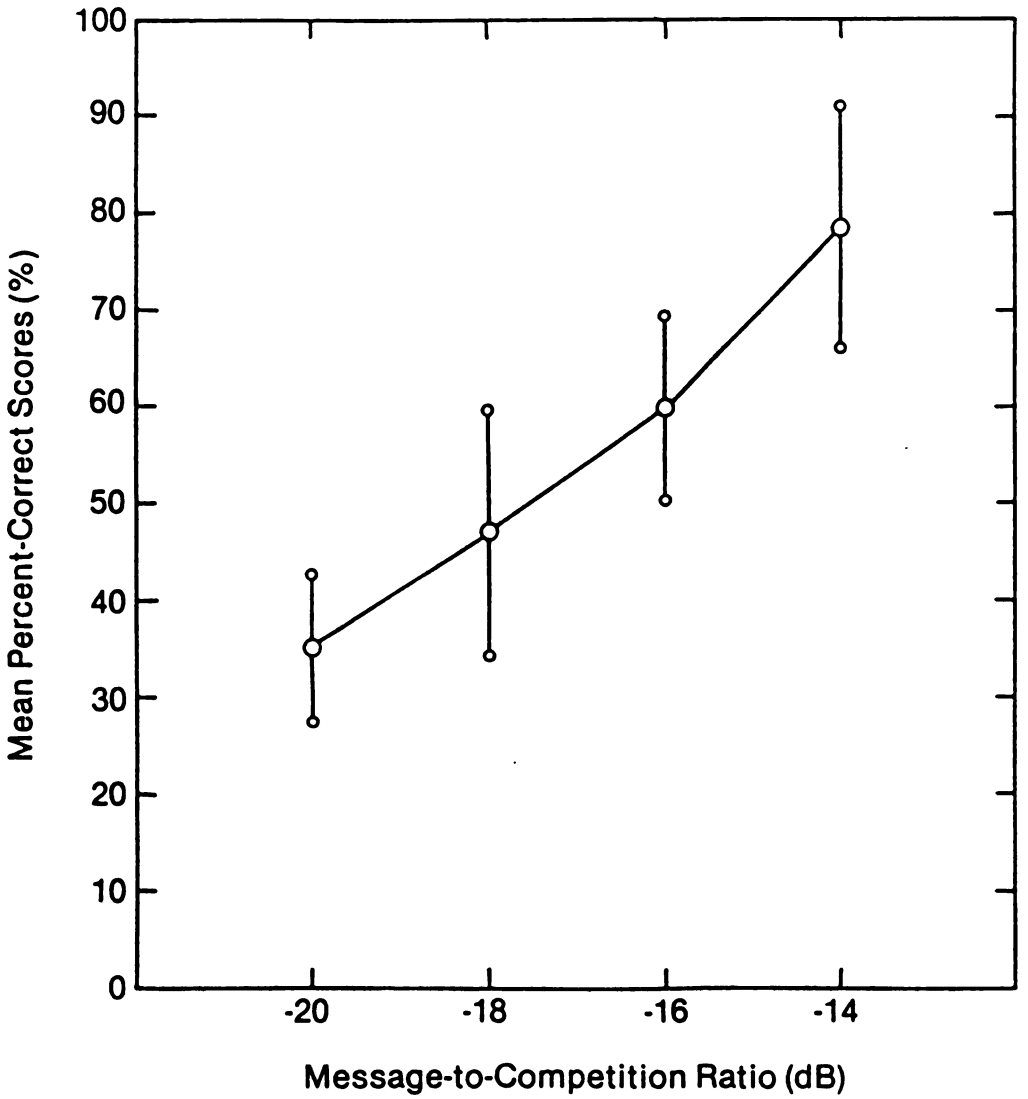

Figure 11. Mean percent-correct scores for competing message MT 8 + DEN 1 as a function of message-to-competition ratio. Each datum represents observations of 12 normal-hearing adult subjects tested monaurally. Vertical lines denote $\pm$ 1 standard deviation.

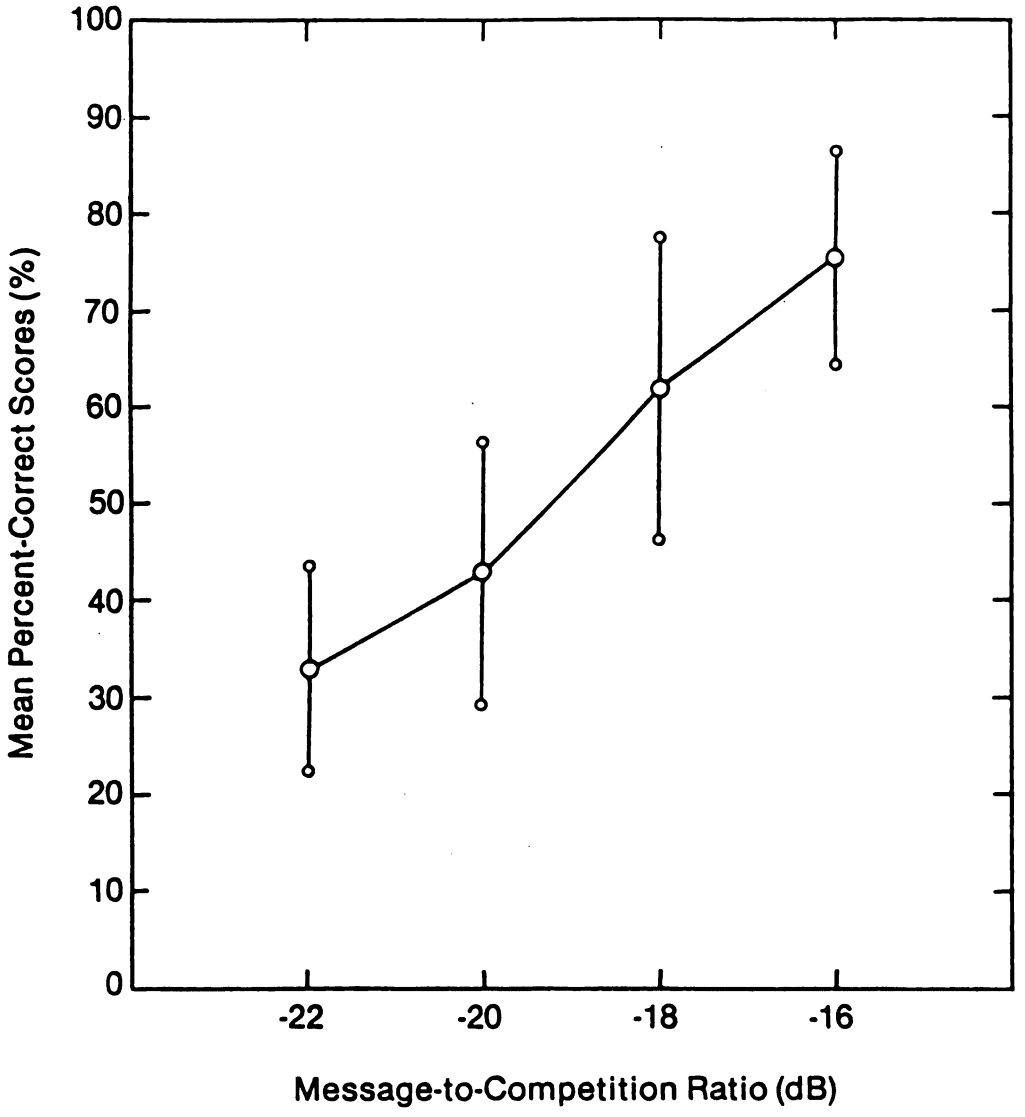

Figure 12. Mean percent-correct scores for competing message DEN MT + 1 as a function of message-to-competition ratio. Each datum represents observations of 12 normal-hearing adult subjects tested monaurally. Vertical lines denote $\pm$ 1 standard deviation.

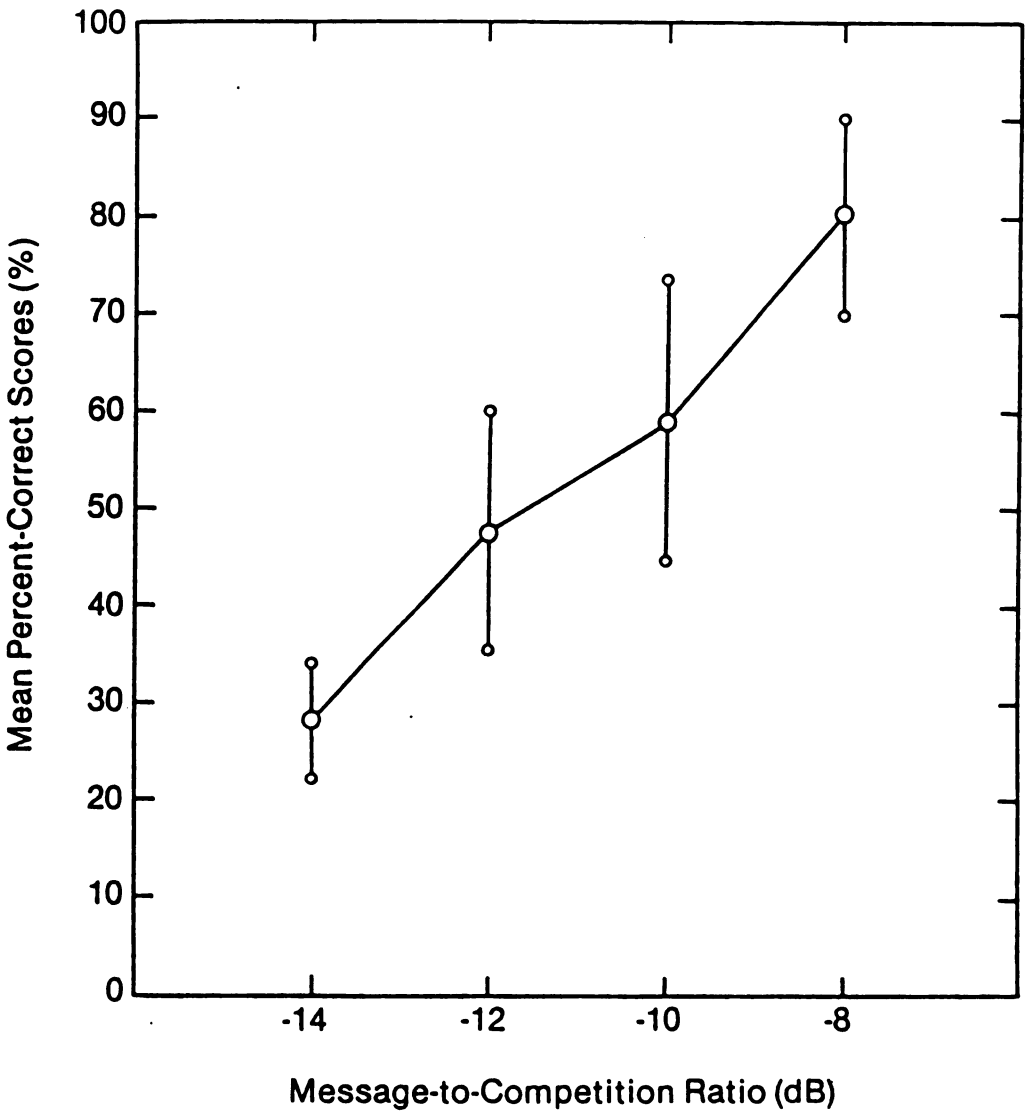

Figure 13. Mean percent-correct scores for competing message MT 8 as a function of message-to-competition ratio. Each datum represents observations of 12 normal-hearing adult subjects tested monaurally. Vertical lines denote $\pm$ 1 standard deviation.

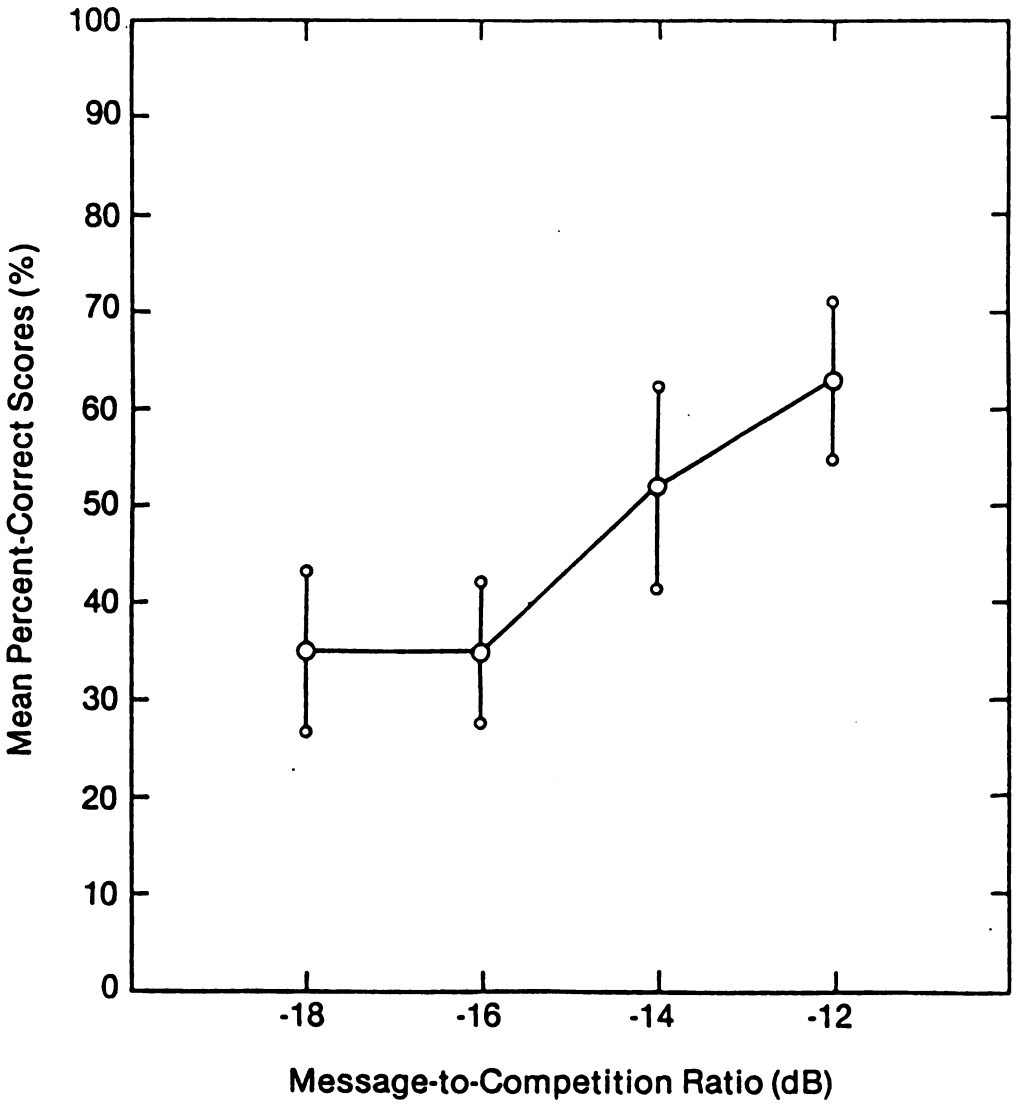

Figure 14. Mean percent-correct scores for competing message DEN MT as a function of message-to-competition ratio. Each datum represents observations of 12 normal-hearing adult subjects tested monaurally. Vertical lines denote $\pm$ 1 standard deviation.

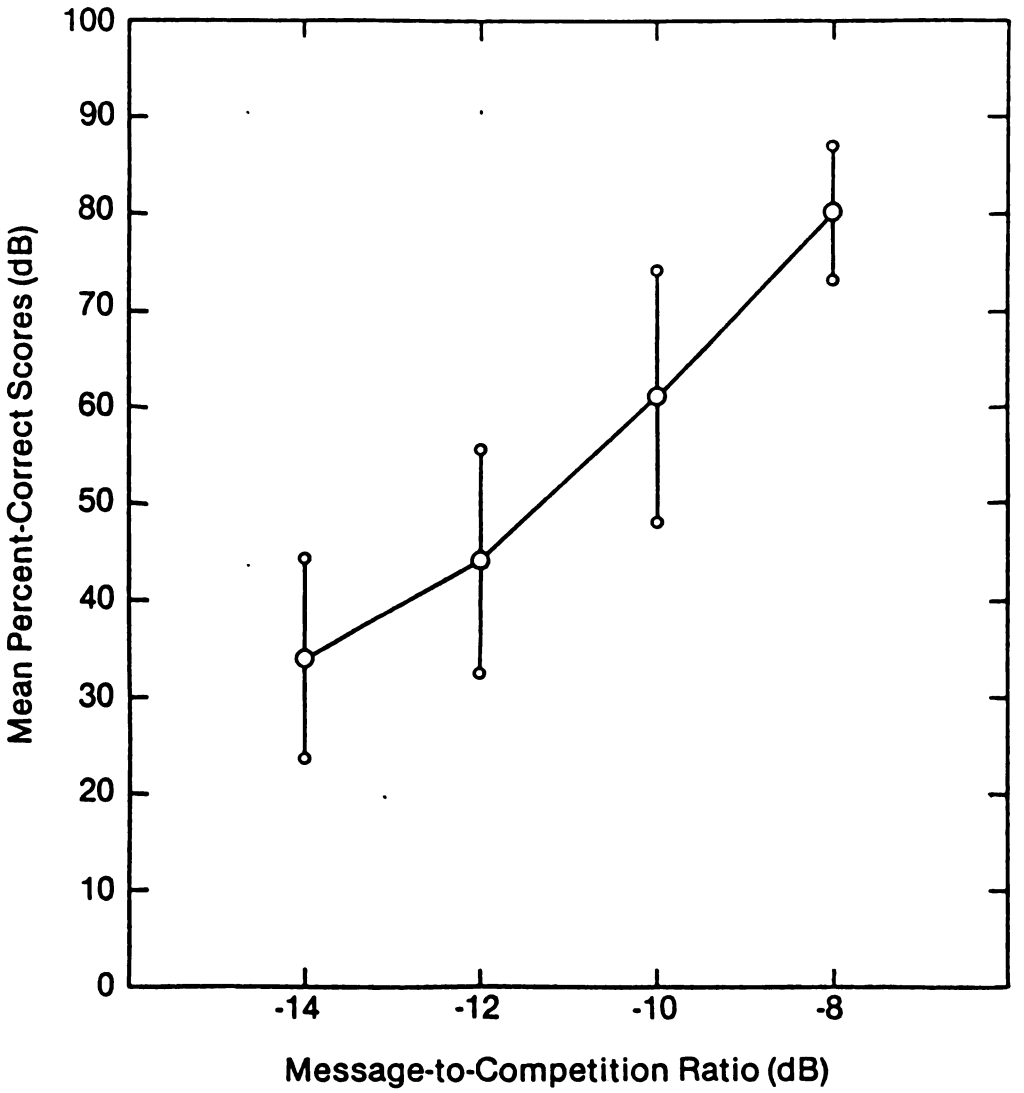

Figure 15. Mean percent-correct scores for competing message MT 8 + 1 as a function of message-to-competition ratio. Each datum represents observations of 12 normal-hearing adult subjects tested monaurally. Vertical lines denote $\pm$ 1 standard deviation.

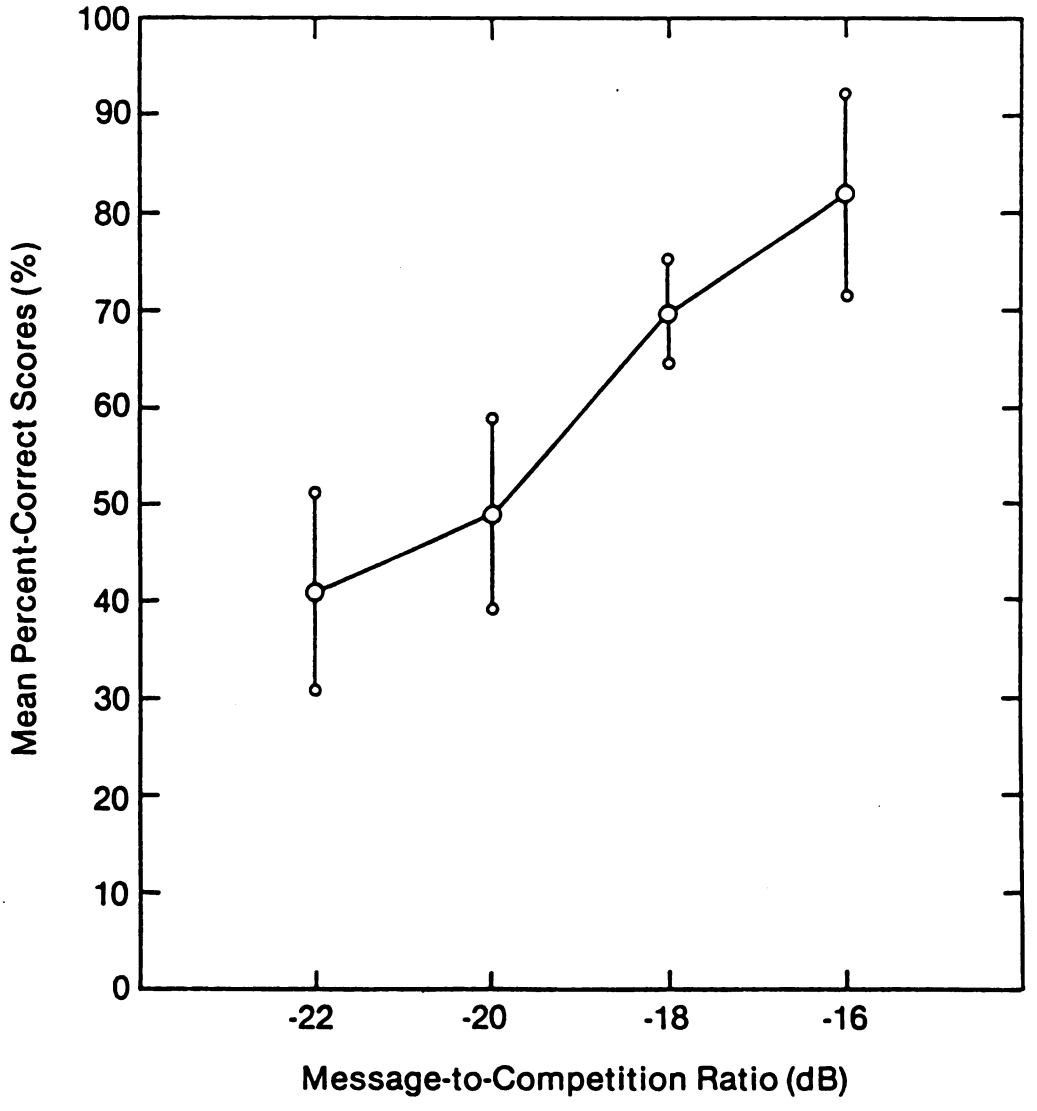

Figure 16. Mean percent-correct scores for competing message DEN MT + DEN 1 as a function of message-to-competition ratio. Each datum represents observations of 12 normal-hearing adult subjects tested monaurally. Vertical lines denote $\pm$ 1 standard deviation.

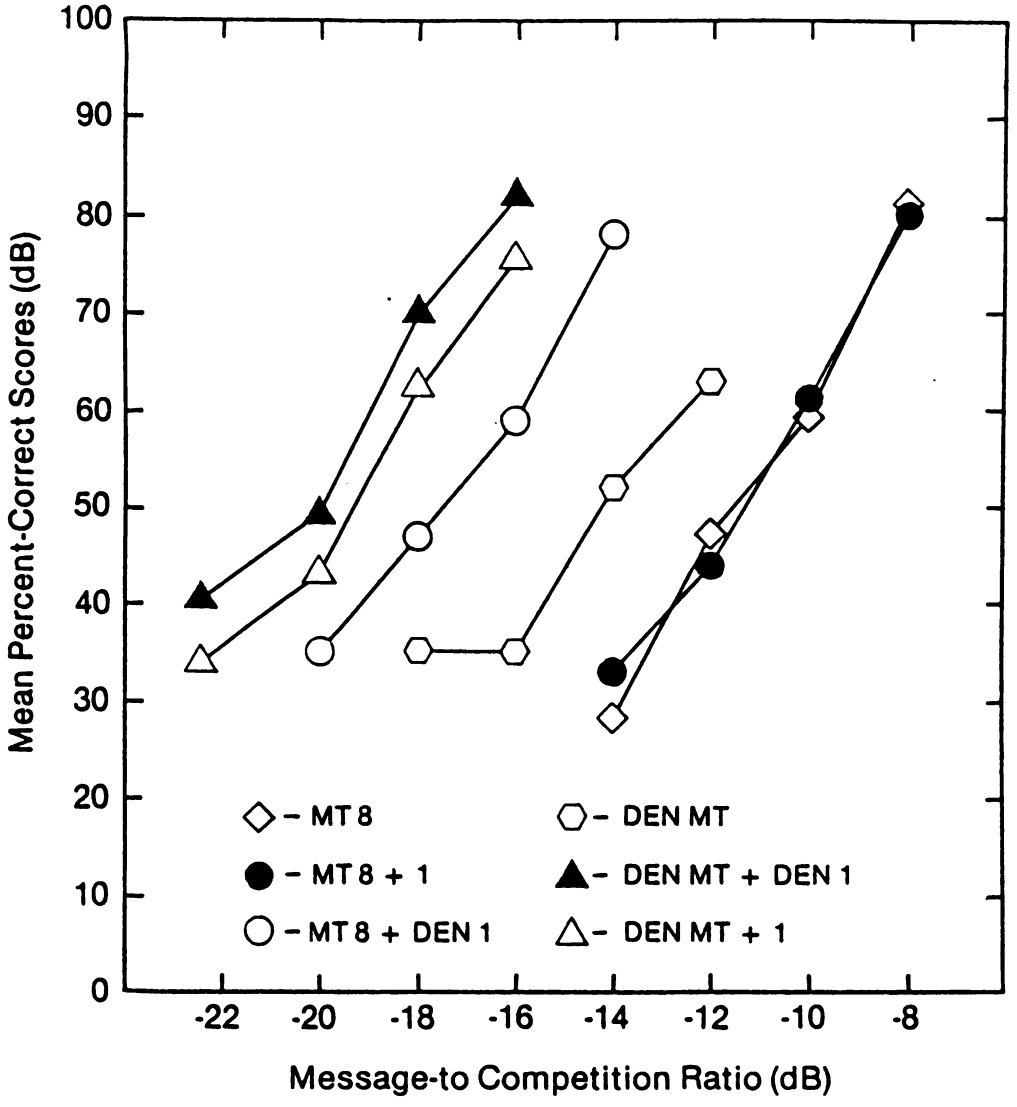

Figure 17. Mean percent-correct scores for six competing message conditions as a function of message-to-competition ratio. Each datum represents the observations of 12 normal-hearing adult subjects tested monaurally.

Table 7. Mean psychometric function slope values, standard deviations, and ranges for the six competing message conditions. Mean psychometric function slope values were determined using linear regression equations computed for each subject.

COMPETING MESSAGE	PSYCHOMETRIC FUNCTION SLOPE VALUES (%/dB) MEAN	S.D.	RANGE
MT 8 + DEN 1	7.0	1.8	6.0
DEN MT + 1	7.3	2.9	6.0
DEN MT	7.4	2.4	8.0
DEN MT + DEN 1	7.3	2.2	7.0
MT 8 + 1	7.8	1.8	5.8
MT 8	8.5	2.1	7.2

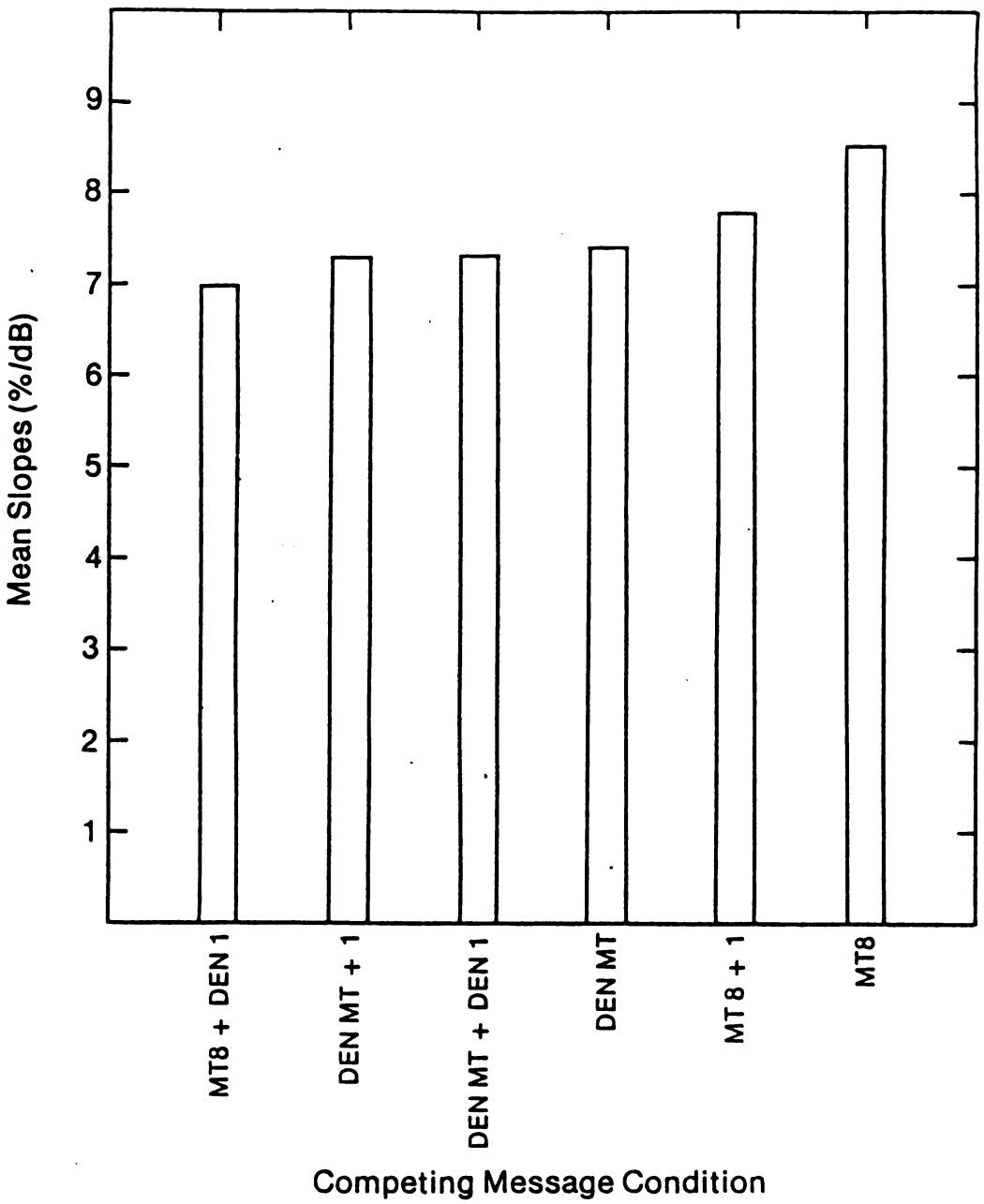

Figure 18. Mean psychometric slope values for the six competing message conditions. Psychometric function slope values were determined for each competing message condition using linear regression equations computed for each subject.

quickly performance improves as the MCR becomes more favorable. The MT 8 competing message exhibits the steepest slope value (8.5%/dB) followed by the MT 8 + 1 competing message (7.8%/dB) and DEN MT competing message (7.4%/dB). Competing messages DEN MT + 1 and DEN MT + DEN 1 had identical psychometric function slopes of 7.3%/dB. The flattest slope value occurred for the MT 8 + DEN 1 competing message (7.0%/dB). Overall, the psychometric function slope values for the six competing messages appear similar, ranging only 1.5%/dB from the flattest slope (MT 8 + DEN 1) to the steepest slope (MT 8).

Table 8 and Figure 19 present mean 50% masking efficiency levels for competing messages according to subject group. These values represent the interpolated MCR at which a 50% performance level would be achieved. Masking efficiency varies appreciably among the competitors, ranging 9.1 dB from the least efficient to the most efficient masker. The MT 8 and MT 8 + 1 competitors are the most efficient maskers with 50% masking efficiency levels of -11.4 and -11.6 dB respectively. The DEN MT competitor is the third most efficient masker (-14.0 dB) whereas the MT 8 + DEN 1, DEN MT + 1, and DEN MT + DEN 1 competing messages are less efficient with levels of -17.7, -19.5, and -20.5 dB respectively.

Reliability of Measurement

Odd-Even Reliability. Table 9 and Figures 20, 21, and 22 summarize intra-list reliability results for the four MCRs of each of the six competing messages. Significant (.10 level) correlations exceeded .497. These coefficients reflect the correlation between the odd-even items in SSI test lists across subjects as a function of MCR and competing message conditions. The response to the first test

Table 8. Mean estimated 50% masking efficiency, standard deviations, and ranges for the six competing message conditions. These levels were estimated from linear regression equations computed for each subject.

COMPETING MESSAGE	50% MASKING EFFICIENCY (dB) MEAN	S.D.	RANGE
MT 8	-11.4	0.5	2.1
MT 8 + 1	-11.6	0.92	1.8
DEN MT	-14.0	0.87	3.3
MT 8 + DEN 1	-17.7	0.65	2.3
DEN MT + 1	-19.5	1.2	4.1
DEN MT + DEN 1	-20.5	0.99	4.1

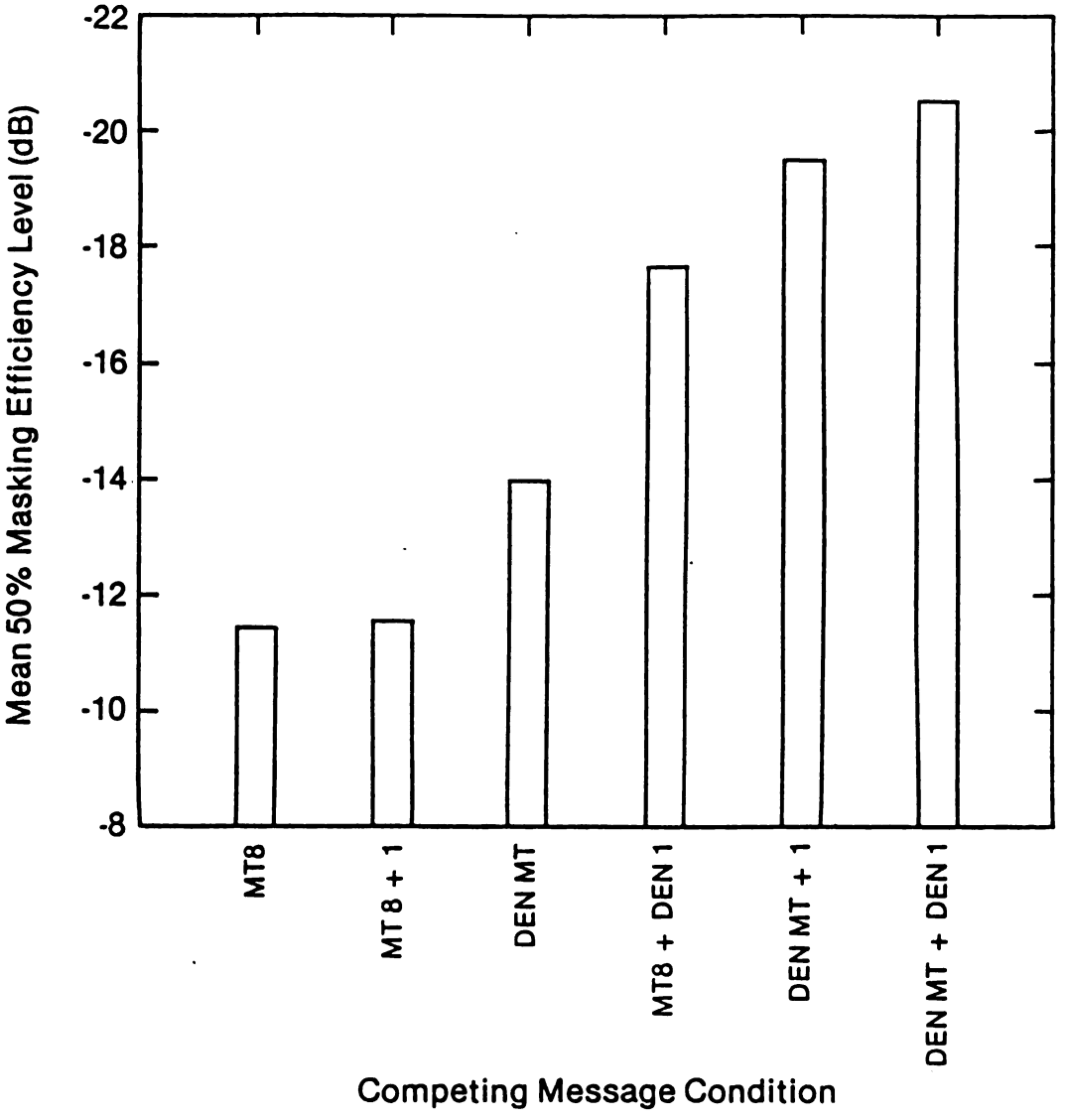

Figure 19. Mean 50% masking efficiency levels for the six competing message conditions. Fifty percent masking efficiency levels were estimated for each competing message condition from linear regression equations computed for each subject.

Table 9. Intra-list reliability correlation coefficients of three experimental groups for their respective competing message conditions as a function of message-to-competition ratio.

GROUP	COMPETING MESSAGE	MESSAGE-TO-COMPETITION RATIO (dB)			
I	MT 8 + DEN 1	- 14	- 16	- 18	- 20
(N - 12)	r	+.61	+.71*	+.75*	+.85*
	DEN MT + 1	- 16	- 18	- 20	- 22
	r	+.77*	+.52*	+.79*	+.32
II	MT 8	- 8	- 10	- 12	- 14
(N = 12)	r	+.74*	+.28	+.10	+.17
	DEN MT	- 12	- 14	- 16	- 18
	r	+.77*	0	+.35	+.61*
III	DEN MT + DEN 1	- 16	- 18	- 20	- 22
(N = 12)	r	+.95*	+.29	+.29	+.48

*Significant beyond P $\alpha \leq .10$ level.

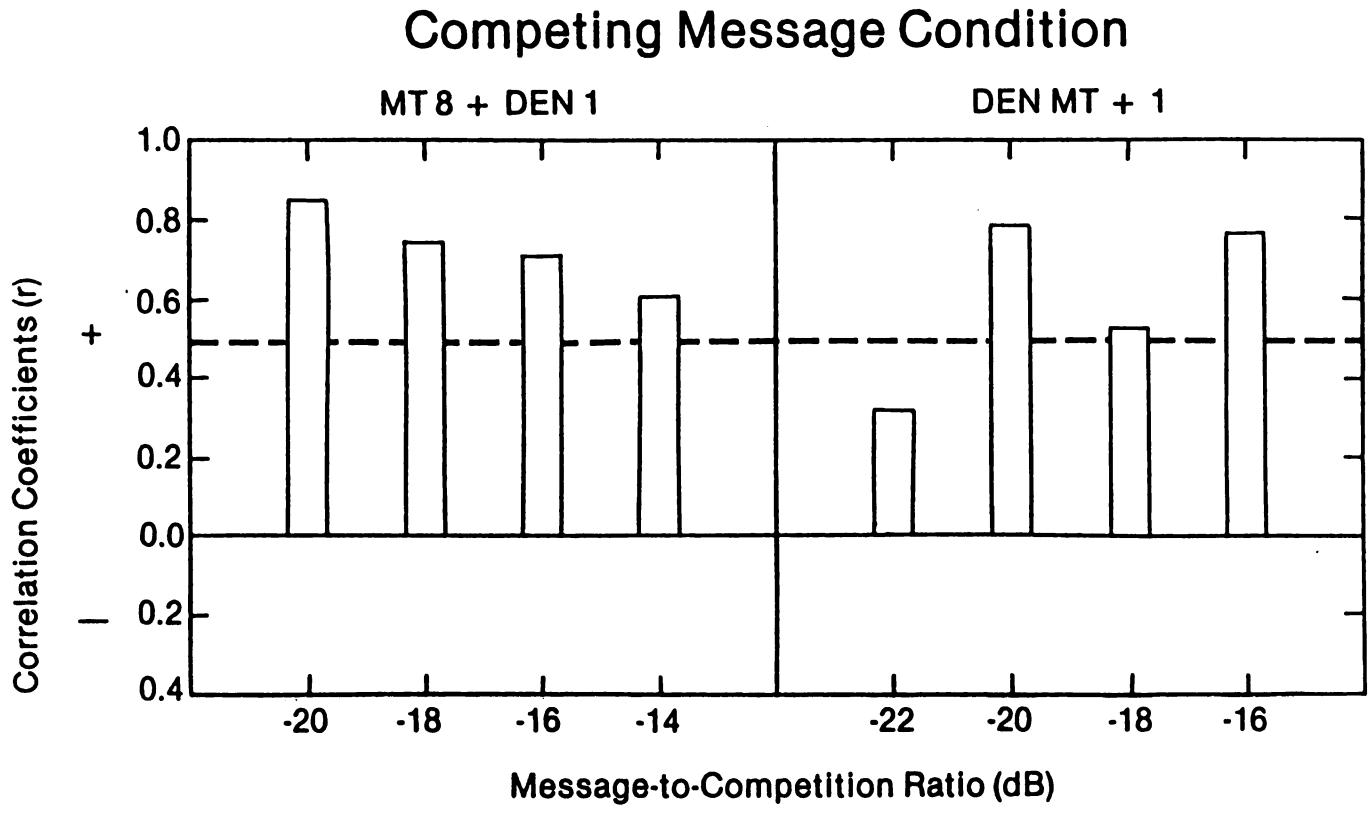

Figure 20. Intra-list reliability correlation coefficients for competing messages MT 8 + DEN 1 and DEN MT + 1 as a function of message-to-competition ratio. Each datum is based on 12 subjects. Significant correlations exceeded .497 at the .10 probability level.

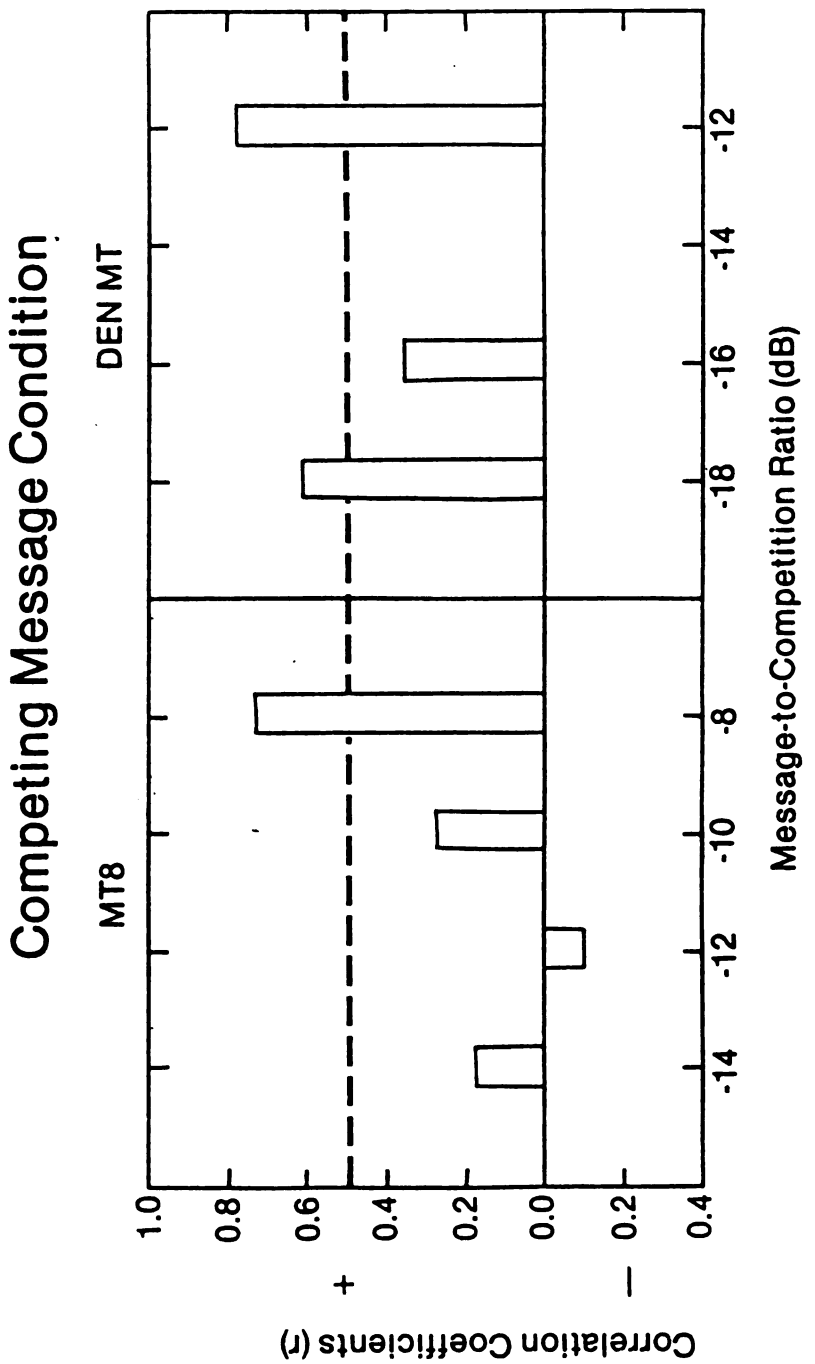

Figure 21. Intra-list reliability correlation coefficients for competing messages MT 8 and DEN MT as a function of message-to-competition ratio. Each datum is based on 12 subjects. Significant correlations exceeded .497 at the .10 probability level.

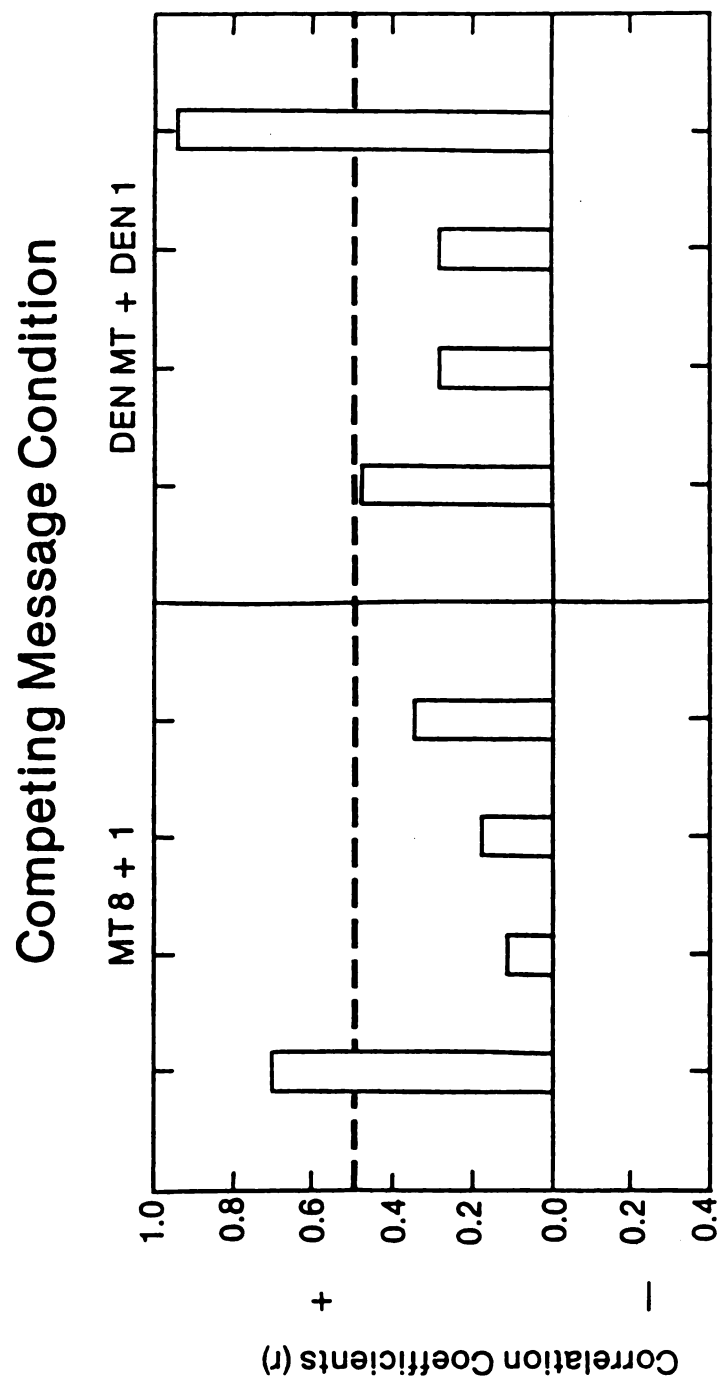

Figure 22. Intra-list reliability correlation coefficients for competing messages MT 8 + 1 and DEN MT + DEN 1 as a function of message-to-competition ratio. Each datum is based on 12 subjects. Significant correlations exceeded .497 at the .10 probability level.

item of each list was omitted when tabulating the responses for each list to provide an equal number of odd and even items (12). Omitting the first item and splitting the list in half reduced the number size from 25 to 12. Therefore, the Spearman-Brown formula (Kerlinger, pg. 438, 1964) was used to correct for the lesser number of items (half-list) used in calculating the coefficients.

Odd-even correlation coefficients for each of the MCRs of individual competing messages were transformed to Z scores, summed, and divided by the number of correlation coefficients (4). The average Z score for each competing message was then re-transformed to a correlation coefficient to yield "average" correlation coefficients for each competing message (see Table 10).

The highest intra-list correlations occurred for the MT 8 + DEN 1 competing message condition (Group I). Correlations as each MCR for this competing message exceeded the significance criterion. Three of four correlations for the DEN MT + 1 competing message (also Group I) also achieved significance. The MT 8 competing message produced poor intra-list reliability, except at the easiest MCR (-8 dB). The DEN MT competing message had a good reliability for the hardest and easiest MCRs, (-18 and -12 dB respectively) but poor reliability for intermediate MCRs. Reliability for the MT 8 + 1 competing message was good only at the hardest MCR (-14 dB) while DEN MT + DEN 1 competing messages exhibited good reliability only at the easiest MCR (-16 dB). Intra-list reliability for the various competing messages did not display any particular pattern as a function of message to competition ratio. However, a pattern of reliability was established as a function of group assignment. Subjects in Group I had good reliability across

Table 10. "Average" intra-list reliability correlation coefficients of three experimental groups across message-to-competition ratios for their respective competing message conditions.

GROUP	COMPETING MESSAGE	"AVERAGE" CORRELATION COEFFICIENTS (r)*
I	MT 8 + DEN 1	+ .74**
(N = 12)	DEN MT + 1	+ .64**
II	MT 8	+ .31
(N = 12)	DEN MT	+ .52**
III	MT 8 + 1	+ .37
(N = 12)	DEN MT + DEN 1	+ .62**

*r to z transformations interpolated from Fisher's z transformation (Bruing and Kintz, pp. 250-251, 1977).

**Significant beyond $P\alpha \leq .10$ level.

all message to competition ratios for both competing messages, except -22 dB for the competing message DEN MT + 1.

The odd-even correlation coefficients calculated are sensitive to performances at the level of the individual subject, but not at the group level. The correlation coefficients do not take advantage of the "averaging out" effect that occurs at the group level. A case in point is the odd-even correlation coefficients obtained at -16 dB MCR for the DEN MT competing message. The odd-even correlation coefficient for this particular experiment is +.35. This relatively low correlation coefficient suggests a significant discrepancy between odd and even item performance. Yet, tabulation of scores across subject group yielded odd and even incorrect responses of 82 and 81, respectively. These results reflect almost perfect agreement between the number of odd incorrect responses and the number of even incorrect responses across the subject group (n = 12).

Binomial Test. The binomial test was employed as an alternative method of assessing intra-list reliability. The binomial test assesses whether there is a significant difference between observed frequencies and expected frequencies. In this study odd and even incorrect responses each have expected frequencies of 50%. That is, 50% of the incorrect items should be odd and 50% should be even. The null hypothesis, then, is incorrect even items = incorrect odd items = 0.5. This hypothesis may be tested using the formula

$$Z = \frac{X - NQ}{\sqrt{NPQ}}$$

where X is the number of odd (or even) items incorrect, N is the total number of incorrect items, P is specified by the null as 0.5, and Q = 1 - P (also 0.5). The resulting Z value is approximately normally distributed with 0 mean and unit variance. Using a two-tailed test and a significance criterion of 0.5, the null hypothesis is rejected if the Z value is less than -1.96 or more than +1.96.

Tables 11 and 12 summarize the percentage of odd-even incorrect items and calculated Z scores for each experimental condition, respectively. In no instance was the binomial test statistically significant. Thus, although odd-even item reliability was not high, odd-even error patterns did not differ significantly.

Test-Retest Reliability. Test-retest correlation coefficients were computed for the six competing message conditions at the MCR value which produced the nearest to 50% correct score for individual subjects (see Table 13 and Figure 23). Significant (.10 level) correlations exceeded .497. The test-retest correlation coefficients ranged from -.33 (DEN MT) to +.84 (MT 8 + 1). If data from the subjects whose second score was at least 24% greater than the first score (possible learning effect) are eliminated, correlation coefficients become more positive, ranging from -.17 to +.87 (see Table 14 and Figure 24). In either case, correlation coefficients are quite variable across the competing message conditions.

Standard Error of Means. The standard error of mean values as a function of MCR for the six competing messages are shown in Table 15. Mean standard error of mean values across competing messages were similar, ranging from 2.6 for the DEN MT stimulus to 3.8 for the DEN MT + 1 stimulus. This indicates that the interval containing the "true"

Table 11. Percent-correct of odd and even items for the six competing messages as a function of message-to-competition ratio. Percentages are rounded off to the nearest whole number.

COMPETING MESSAGE	MESSAGE-TO-COMPETITION RATIO (dB)			
MT 8 + DEN 1	- 14	- 16	- 18	- 20
% Odd	52	48	46	49
% Even	48	52	54	51
DEN MT + 1	- 16	- 18	- 20	- 22
% Odd	52	51	52	48
% Even	48	49	48	52
MT 8	- 8	- 10	- 12	- 14
% Odd	55	50	50	49
% Even	45	50	50	51
DEN MT	- 12	- 14	- 16	- 18
% Odd	49	58	50	50
% Even	51	42	50	50
MT 8 + 1	- 8	- 10	- 12	- 14
% Odd	56	51	49	53
% Even	44	49	51	47
DEN MT + DEN 1	- 16	- 18	- 20	- 22
% Odd	59	48	50	49
% Even	41	52	50	51

Table 12. Z values for the six competing message conditions as a function of message-to-competition ratio. Equivalency of odd and even item correct rate is assumed if Z value is less than - 1.96 or greater than + 1.96.

COMPETING MESSAGES	MESSAGE-TO-COMPETITION RATIO (dB)			
MT 8 + DEN 1	- 14	- 16	- 18	- 20
Z value	.35	.37	1.15	.22
DEN MT + 1	- 16	- 18	- 20	- 22
Z value	.34	.19	.47	.44
MT 8	- 8	- 10	- 12	- 14
Z value	.90	.09	.15	.29
DEN MT	- 12	- 14	- 16	- 18
Z value	.21	1.32	.08	.21
MT 8 + 1	- 8	- 10	- 12	- 14
Z value	.85	.19	.16	.73
DEN MT + DEN 1	- 16	- 18	- 20	- 22
Z value	1.43	.32	.08	.05

Table 13. Test-retest correlation coefficients (Pearson r) for six competing messages. Test-retest measurements were obtained at the message-to-competition ratio which produced the nearest to 50%-correct score for each subject.

COMPETING MESSAGE	TEST-RETEST CORRELATION COEFFICIENTS (r)
MT 8 + DEN 1 (N = 12)	+ .36
DEN MT + 1 (N = 12)	+ .36
MT 8 (N = 12)	- .05
DEN MT (N = 12)	- .33
MT 8 + 1 (N = 12)	+ .84*
DEN MT + DEN 1 (N = 12)	+ .35

*Significant beyond $P\alpha \leq .10$ level.

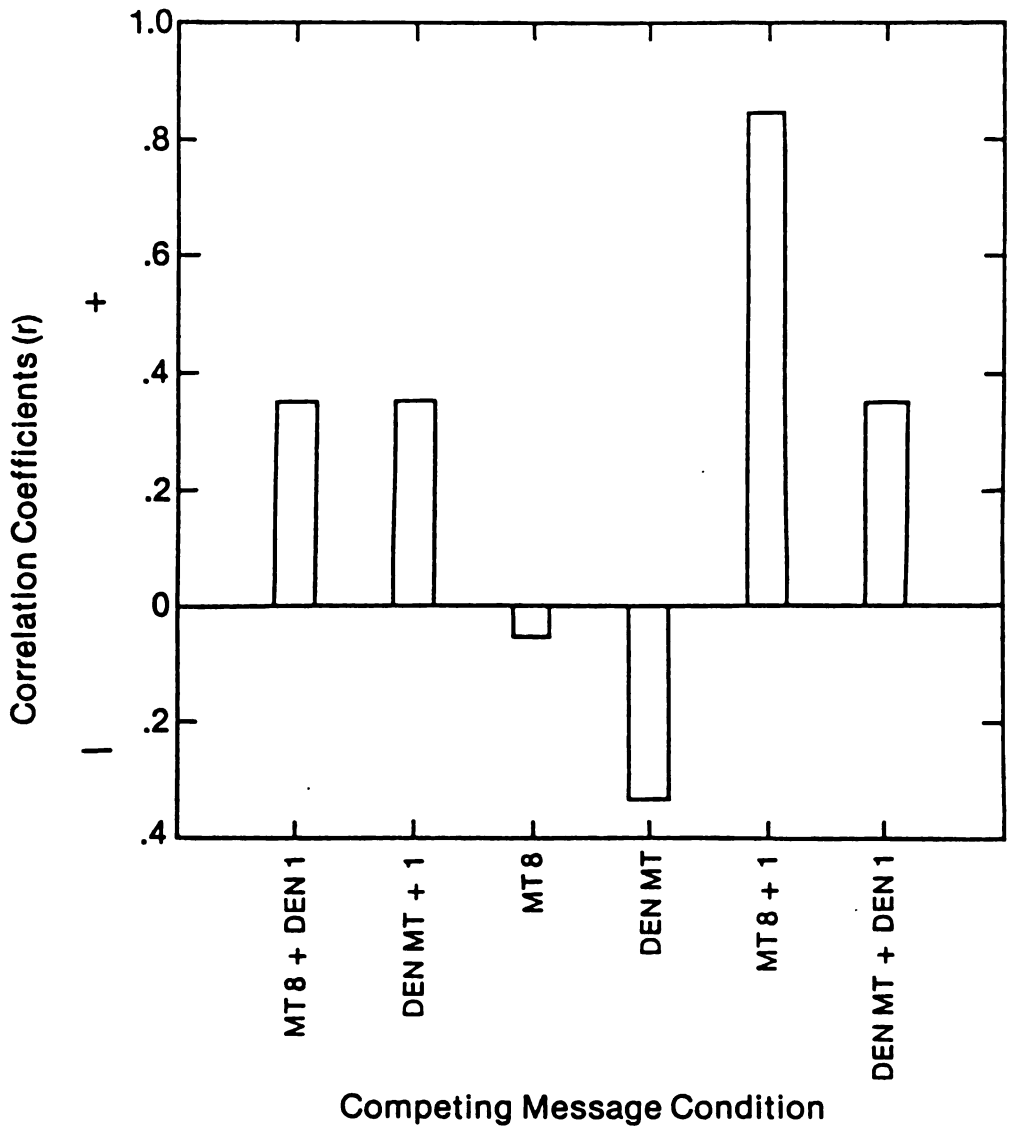

Figure 23. Test-retest correlation coefficients for six competing messages. Test-retest measurements were obtained at the message-to-competition ratio which produced the nearest to 50%-correct score for each subject.

Table 14. Test-retest correlation coefficients for the six competing message conditions if data are eliminated from subjects whose second scores were 24% greater than the first. Test-retest measurements were obtained at the message-to-competition ratio which produced the nearest to 50%-correct score for each subject.

COMPETING MESSAGE	TEST-RETEST CORRELATION COEFFICIENTS (r)
MT 8 + DEN 1 (N = 12)	+ .36
DEN MT + 1 (N = 10)	+ .70*
MT 8 (N = 10)	+ .29
DEN MT (N = 8)	- .17
MT 8 + 1 (N = 11)	+ .87*
DEN MT + DEN 1 (N = 11)	+ .50*

*Significant beyond P $\alpha \leq .10$ level.

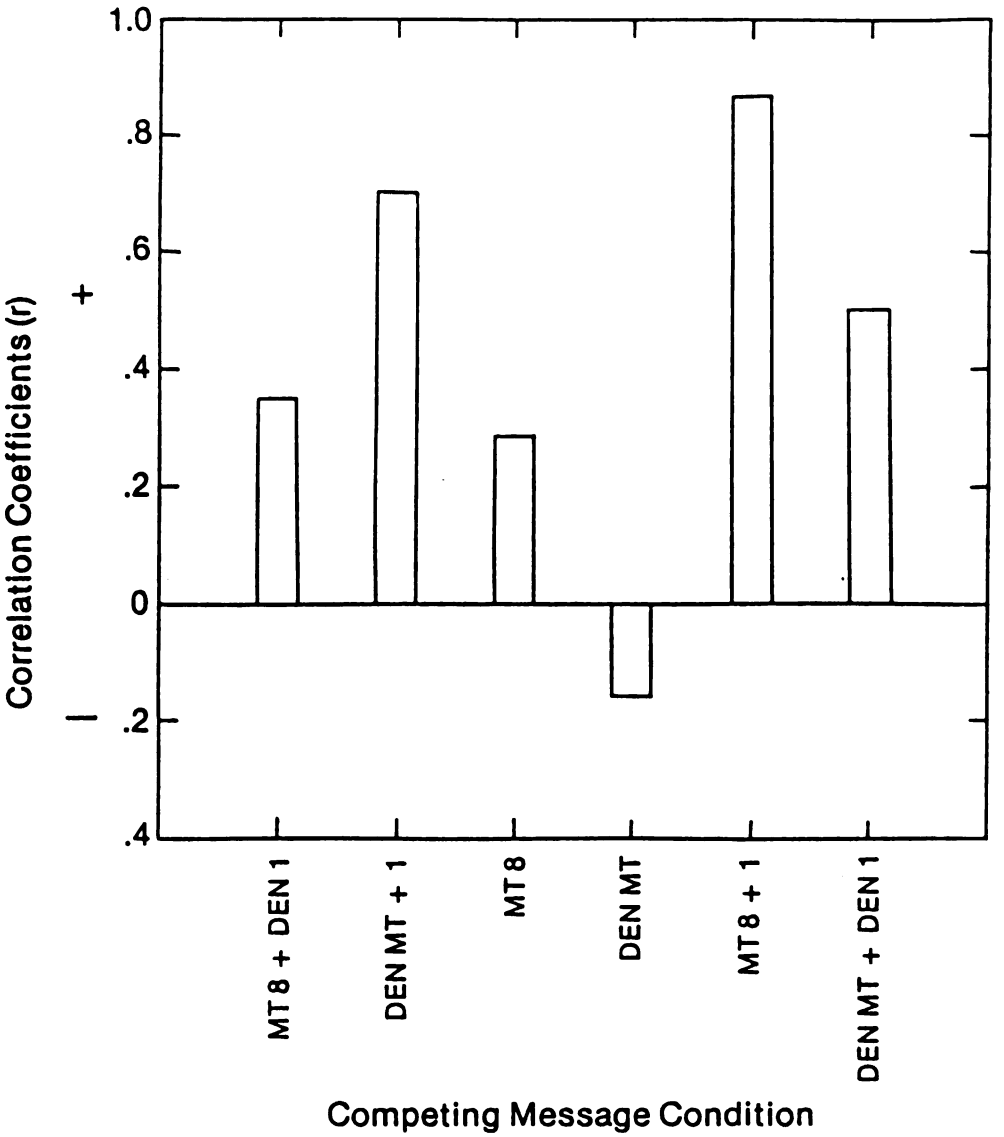

Figure 24. Test-retest correlation coefficients for six competing messages if data are eliminated from subjects whose second scores were 24% greater than the first. Test-retest measurements were obtained at the message-to-competition ratio which produced the nearest to 50%-correct score for each subject.

Table 15. Standard error of the mean (SEM) for six competing messages as a function of message-to-competition ratio (N = 12). Also shown is mean SEM across message-to-competition ratios for each competing message.

COMPETING MESSAGE	MESSAGE-TO-COMPETITION RATIO (dB)				MEAN SEM
MT 8 + DEN 1	- 14	- 16	- 18	- 20	3.0
SEM	3.6	2.6	3.8	2.3	
DEN MT + 1	- 16	- 18	- 20	- 22	3.6
SEM	3.4	4.7	4.0	3.3	
MT 8	- 8	- 10	- 12	- 14	3.2
SEM	3.0	4.3	3.6	1.8	
DEN MT	- 12	- 14	- 16	- 18	2.6
SEM	2.5	3.2	2.2	2.5	
MT 8 + 1	- 8	- 10	- 12	- 14	3.2
SEM	2.3	4.0	3.5	3.2	
DEN MT + DEN 1	- 16	- 18	- 20	- 22	2.8
SEM	3.2	1.7	3.0	3.2	

mean score is similar in size across competitors. In other words, precision of measurement appears to be fairly equivalent among the six competing messages.

Inferential Analysis

The statistical analysis included several ANOVA's of psychometric function slope values and 50% masking efficiency levels. Significant F-ratios exceeded critical values at the .05 level.

Psychometric Function Slope Values. Tables 16 through 22 summarize the one-way within-subject and one-way between-subject ANOVA's of psychometric function slopes for the various competing message conditions. ANOVA of the psychometric function slope for the MT 8 versus DEN MT competing message comparison (Table 16) investigates semantic content in a single-ground competing message. Tables 17, 18, and 19 contain ANOVA results of three competing message pairs designed to examine possible differences in psychometric function slopes as a function of differences in a foreground-background competing message containing semantic content in (1) background only, (2) foreground only, and (3) background and foreground. Table 20 presents ANOVA results of competing messages MT 8 + DEN 1 and DEN MT + 1. This comparison examines the effect of the position and type of semantic content in a foreground-background competing message. The ANOVA results of psychometric function slopes of competing messages MT 8, MT 8 + 1 and MT 8 + DEN 1 are shown in Table 21. This comparison was made to determine the effect on psychometric function slope of changing the foreground status in a competing message containing a speech background. An ANOVA of DEN MT, DEN MT + 1 and

Table 16. One-way within-subject analysis of variance of psychometric function slope values for competing messages MT 8 and DEN MT.

SOURCE	dF	SS	MS	F_{obs}	$F_{crt} = .05$	η^2
Competitor (A)	1	17	17	15.04**	4.84*	0.14
Subjects (S)	11	89.5				
A x S	11	12.5	1.13			
Total	23	119				

*From F distribution table (Winer, pp. 804-869, 1971)

**Significant beyond $P\alpha \leq .05$ level.

Table 17. One-way between-subject analysis of variance of psychometric function slope values for competing messages MT 8 + DEN 1 and DEN MT + DEN 1.

SOURCE	dF	SS	MS	F_{obs}	$F_{crt} = .05$
Competitor	1	.6	.6	.14	4.30*
Error	23	91.7	4.16		
Total	24	87.6			

*From F distribution table (Winer, pp. 804-869, 1971)

Table 18. One-way between-subject analysis of variance of psychometric function slope values for competing messages DEN MT = 1 and DEN MT + DEN 1.

SOURCE	dF	SS	MS	F_{obs}	F_{crt} = .05
Competitor	1	6	6	2.5	4.30*
Error	23	56	2.4		
Total	24	62			

*From F distribution table (Winer, pp. 804-869, 1971)

Table 19. One-way within-subject analysis of variance of psychometric function slope values for competing messages MT 8 + 1 and DEN MT + DEN 1.

SOURCE	dF	SS	MS	F_{obs}	$F_{crt} = .05$
Competitor	1	1.5	1.5	0.88	4.84*
Subjects(S)	11	71.3			
A x S	11	18.8	1.7		
Total	23	91.6			

*From F distribution table (Winer, pp. 804-869, 1971)

Table 20. One-way within-subject analysis of variance of psychometric function slope values for competing messages MT 8 + DEN 1 and DEN MT + 1.

SOURCE	dF	SS	MS	F_{obs}	$F_{crt} = .05$
Competitor	1	0.5	0.5	0.18	4.84*
Subject (S)	11	99.7			
A x S	11	29.1	2.65		
Total	23	129.3			

*From F distribution table (Winer, pp. 804-869, 1971)

Table 21. One-way between-subject analysis of variance of psychometric function slope values for competing messages MT 8, MT 8 + 1, and MT 8 + DEN 1 (Group N = 12).

SOURCE	dF	SS	MS	F_{obs}	$F_{crt} = .05$
Competitor	2	13	6.5	1.8	4.14*
Error	33	120	3.6		
Total	35	133	10.1		

*From F distribution table (Winer, pp. 804-869, 1971)

Table 22. One-way between-subject analysis of variance of psychometric function slope values for competing messages DEN MT, DEN MT + 1, and DEN MT + DEN 1.

SOURCE	dF	SS	MS	F_{obs}	$F_{crt} = .05$
Competitor	2	0.07	0.035	0.005	4.14*
Error	33	210.6	6.4		
Total	35	210.67	6.435		

*From F distribution table (Winer, pp. 804-869, 1971)

DEN MT + DEN 1 stimuli psychometric function slope values (Table 22) was performed to determine the effect on psychometric function slopes of changing the foreground status in a noise background competing message.

None of these analyses revealed significant differences in mean psychometric function slopes, except for the MT 8 versus DEN MT comparison. Thus, the semantic content factor in the various experimental conditions generally had no effect upon SSI slopes.

Two considerations qualify the significance of the single-ground competing message semantic content effect on psychometric function slope values. First, an ETA-squared value of .14 indicates that only a small portion of the variance in slope can be attributed to the semantic content factor. Second, slope values for the DEN MT competing message were computed on the basis of three MCRs while slope values for the MT 8 competing message were computed using all four MCRs. Different computation procedures may have created an artifactual disparity between the psychometric function slopes of the two competing messages, especially since the slope of the MT 8 competing message rises more sharply from the third MCR (-10 dB) to the fourth MCR (-8 dB) than any other competing message. A comparison of psychometric function slope values computed on the basis of three MCRs for both competing messages was not possible because several subjects had not reached the 60% correct level by the third MCR (-10 dB) for the MT 8 competing message. Psychometric function slope values computed using mean scores at three corresponding MCRs (i.e., linear portion of psychometric function) revealed similar slopes of 7%/dB and 7.5/dB for the DEN MT and MT 8 competing messages,

respectively.

Fifty Percent Masking Efficiency Levels. Tables 23 through 28 summarize results of the ANOVA's of 50% masking efficiency levels for the various competing message comparisons. Several of the ANOVA's produced significant results; each will be discussed separately.

The MT 8 versus DEN MT competing message comparison examines the effect of single-ground competing message semantic content on 50% masking efficiency levels. Table 23 contains the one-way within-subject ANOVA for these competitors. The analysis indicates a significant semantic content effect for the single-ground competing message. The ETA-squared value indicates 34% of the dependent variable score can be accounted for by the semantic content factor, suggesting a mild-to-moderate experimental effect.

Three pairs of competitors were compared to investigate possible differences in masking efficiency levels as a function of differences in a foreground-background competing message containing semantic content in (1) background only, (2) foreground only, and (3) background and foreground. Table 24 displays the result of the one-way between-subject ANOVA of masking efficiency levels for competing messages MT 8 + DEN 1 and DEN MT + DEN 1. A significant difference in the mean 50% masking efficiency levels of the two competing messages was determined, indicating a significant background semantic content effect. The OMEGA-squared value is .39, suggesting approximately 40% of the score variance can be attributed to background semantic content. Again, this indicates a mild-to-moderate experimental effect. ANOVA results of the competing messages DEN MT + 1 and DEN MT + DEN 1 masking

Table 23. One-way within-subject analysis of variance of 50% masking efficiency levels for competing messages MT 8 and DEN MT.

SOURCE	dF	SS	MS	F_{obs}	F_{crt} = .05	ω^2
Competitor (A)	1	20	20	13.3**	4.84*	0.34
Subjects (S)	11	21				
A x S	11	17	1.54			
Total	23	58				

*From F distribution table (Winer, pp. 804-869, 1971)

**Significant beyond P $\alpha \leq .05$ level.

Table 24. One-way between-subject analysis of variance of 50% masking efficiency levels for competing messages MT 8 + DEN 1 and DEN MT + DEN 1.

SOURCE	dF	SS	MS	F_{obs}	$F_{crt} = .05$	ω^2
Competitor	1	47.1	47.1	16.52**	4.30*	.39
Error	23	62.8	2.85			
Total	24	109.9				

*From F distribution table (Winer, pp. 804-869, 1971)

**Significant beyond P $\alpha \leq .05$ level.

Table 25. One-way between-subject analysis of variance of 50% masking efficiency levels for competing messages DEN MT + 1 and DEN MT + DEN 1.

SOURCE	dF	SS	MS	F_{obs}	F_{crt} = .05
Competitor	1	6	6	2.36	4.30*
Error	23	56	2.54		
Total	24	62			

*From F distribution table (Winer, pp. 804-869, 1971)

Table 26. One-way within-subject analysis of variance of 50% masking efficiency levels for competing messages MT 8 + 1 and DEN MT + DEN 1.

SOURCE	dF	SS	MS	F_{obs}	F_{crt} = .05	η^2
Competitor (A)	1	485	485	404**	4.84*	.96
Subject (S)	11	6.7				
A x S	11	13.3	1.2			
Total	23	505				

*From F distribution table (Winer, pp. 804-869, 1971)

**Significant beyond P $\alpha \leq .05$ level.

Table 27. One-way within-subject analysis of variance of 50% masking efficiency levels for competing messages MT 8 + DEN 1 and DEN MT + 1.

SOURCE	dF	SS	MS	F_{obs}	F_{crt} = .05	η^2
Competitor (A)	1	20	20	13.3**	4.84*	.34
Subject (S)	11	32				
A x S	11	17	1.5			
Total	23	58				

*From F distribution table (Winer, pp. 804-869, 1971)

**Significant beyond P $\alpha \leq .05$ level.

Table 28. One-way between-subject analysis of variance of 50% masking efficiency levels for competing messages MT 8, MT 8 + 1, and MT 8 + DEN 1.

SOURCE	dF	SS	MS	F_{obs}	F_{crt} = .05	ω^2
Competitor	2	313	156.6	16.14**	4.14*	.37
Error	33	323.8	9.8			
Total	35	636.8	166.4			

*From F distribution table (Winer, pp. 804-869, 1971)

**Significant beyond P $\alpha \leq .05$ level.

efficiency levels (Table 25) indicate no significant foreground semantic content effect. Table 24 contains the results of the one-way within-subject ANOVA of competing messages MT 8 + 1 and DEN MT + DEN 1 50% masking efficiency levels. This analysis indicates a significant foreground-background content effect. ETA-squared suggests a very high percentage of score variance (96%) can be accounted for by the foreground-background semantic content factor. Collectively, these three analyses indicate semantic content has a significant effect on masking efficiency levels when it occurs in the background (multi-talker) or background and foreground (multi-talker and single-talker). Single-talker foreground semantic content does not exhibit a significant experimental effect.

The MT 8 + DEN 1 and DEN MT + 1 competing message comparison was intended to investigate the effect of semantic content position and type on masking efficiency. The MT 8 + DEN 1 competing message has a multi-talker background with a single-talker speech modulated noise foreground. Conversely, the DEN MT + 1 competitor has a multi-talker speech modulated noise background and a single-talker foreground. The ANOVA results in Table 27 reveal a significant experimental defect for semantic content position and type. The ETA-squared value (.34) suggests a mild-to-moderate experimental effect. It is important to note that this comparison examines two aspects of semantic content simultaneously.

Mean 50% masking efficiency levels obtained using the MT 8, MT 8 + 1, and MT 8 + DEN 1 competitors were compared to determine the effect of changing foreground status in a competing message containing a speech background. The ANOVA results shown in Table 28 indicate a significant

difference in 50% masking efficiency levels among the three competitors. The experimental effect, estimated by OMEGA-squared, was mild-to-moderate (.37). Tukey's test of specific comparisons revealed the MT 8 + DEN 1 competing message 50% masking efficiency level differs from those of the MT 8 and MT 8 + 1 competing messages, but the masking efficiency levels of the latter two competitors do not differ from each other (see Table 29). Thus, a differential effect occurred only when the noise foreground was coupled to the speech background.

A final comparison determined the effect on masking efficiency of changing the foreground status in a noise background competing message. Table 30 displays the ANOVA result for competing messages DEN MT, DEN MT + 1, and DEN MT + DEN 1. The significant F-ratio indicates a significant difference in mean 50% masking efficiency levels among the three competing messages. The .74 OMEGA-squared value reflects a relatively strong experimental effect. Tukey's test of specific comparisons reveal a differential experimental effect occurred for the DEN MT competing message only (see Table 31). The effects of competing messages DEN MT + 1 and DEN MT + DEN 1 on 50% masking efficiency levels were equivalent.

SUMMARY

SSI performance scores were obtained as a function of MCR for six different competing message conditions. Mean psychometric functions were determined from individual subject data. The general configurations of all six mean psychometric functions were similar. Various aspects of test reliability were estimated using several

Table 29. Tukey's test of specific comparisons of mean 50% masking efficiency levels for competing messages MT 8, MT 8 + 1, and MT 8 + DEN 1.

	MT 8 (-11.4)	MT 8 + 1 (-11.6)	MT 8 + DEN 1 (-17.7)
MT 8 (-11.4)	--	-0.2	-6.3*
MT 8 + 1 (-11.6)		--	-6.2*
MT 8 + DEN 1 (-17.7)			--

*Exceeds critical value (mean) at .05 probability level.

Table 30. One-way between-subject analysis of variance of 50% masking efficiency levels for competing messages DEN MT, DEN MT + 1, and DEN MT + DEN 1.

SOURCE	dF	SS	MS	F_{obs}	$F_{crt} = .05$	ω^2
Competitor	2	294	147	54.4**	4.14*	0.74
Error	33	92	2.7			
Total	35	386	149.7			

*From F distribution table (Winer, pp. 804-869, 1971)

**Significant beyond P $\alpha \leq .05$ level.

Table 31. Tukey's test of specific comparisons of mean 50% masking efficiency levels for competing messages DEN MT, DEN MT + 1, and DEN MT + DEN 1.

50% MASKING EFFICIENCY MEANS AND MEAN DIFFERENCES (dB)

	DEN MT (-14.0)	DEN MT + L (-19.5)	DEN MT + DEN 1 (-20.5)
DEN MT (-14.0)	--	-5.5*	-6.5*
DEN MT + 1 (-19.5)		--	-1.0
DEN MT + DEN 1 (-20.5)			--

*Exceeds critical value (mean) at .05 probability level.

statistical procedures. Test-retest reliability was lower than expected for most competing message conditions. However, test-retest data was obtained within the most variable portion of the psychometric function and the correlation coefficients should be considered very conservative estimates of test-retest reliability. Intra-list reliability was assessed using the odd-even method and the binomial test. These procedures failed to reveal any significant differences in odd item versus even item performance. SEMs calculated for this study were, generally, much smaller than SEMs calculated for the other SSI studies reporting dispersion data.

Mean psychometric function slope values for the six competing messages were similar, ranging from 7.0%/dB for the MT 8 + DEN 1 competing message to 8.5%/dB for the MT 8 + 1 competing message. The relatively narrow range in which these values occur indicates that semantic content had little, if any, effect on how quickly performance rises as a function of changing MCRs.

Masking efficiency varied significantly as a function of competing message condition. The MT 8 and DEN MT comparison revealed that semantic content caused an increase in masking efficiency (2.6 dB) in a single-ground continuous spectrum competing message. The effect of semantic content was also determined for foreground-background competing messages having temporally continuous backgrounds and temporally discontinuous foregrounds. Generally, semantic content had little effect on masking efficiency when it occurred only in the temporally continuous background or temporally discontinuous foreground. However, semantic content in a temporally discontinuous foreground and

in a temporally continuous background had a marked effect on masking efficiency.

CHAPTER IV

DISCUSSION

INTRODUCTION

Chapter III describes the ipsilateral competing message SSI test performance of 36 normal-hearing subjects divided equally into three experimental groups. Each group listened monaurally to SSI target sentences in the presence of two different competing messages at each of four MCRs. Mean psychometric functions were determined from individual subject data. The two dependent variables of psychometric function slope values and 50% masking efficiency levels were derived from individual psychometric functions. Psychometric function slope values indicate how quickly performance changes as a function of MCR, whereas 50% masking efficiency levels estimate the MCR at which a 50% correct performance should be achieved. The psychometric function slope values and 50% masking efficiency levels were analyzed to determine significant differences as a function of competing message condition. When significant differences were found (.05 level) appropriate strengths of association measures were used to determine the amount of dependent variable variance accounted for by the independent variable. A discussion of the experimental findings and their implications follow.

EXPERIMENTAL FINDINGS

Reliability

Odd-Even and the Binomial Test. The use of odd-even correlation coefficients and the binomial test to assess intra-list reliability allows examination of two aspects of response consistency at the level of the item. The odd-even method indicates a fair amount of variability among individual subjects in the number of the respective odd and even incorrect responses, whereas the binomial test suggests the lack of a difference between odd and even item incorrect response rates at the group level. Close agreement between the percentage correct of response items across subject group when several individual subjects within the group exhibit poor agreement between odd and even performance indicates differences in individual odd and even performances are random in nature. That is, the experimental procedure did not systematically favor either odd or even item performance.

Test-Retest Reliability. Test reliability across successive administration of the SSI test was assessed by retesting all subjects at both competing message conditions. Generally, test-retest reliability was low to moderate except for the MT 8 + 1 competing message. This competitor exhibited a test-retest correlation coefficient of +.84, indicating highly consistent performances across successive test presentations. Several factors may have contributed to the relatively low test-retest reliability for five of the six competing messages.

An obvious potential hindrance to high test-retest reliability in the present study was learning effect. It is possible subjects learned to deal with the competing messages. Most subjects stated

they adopted one or more strategies during the course of the test procedure. Jerger (1970) noted that subject strategies ranged from listening for entire sentences at easy MCRs, listening for words or word pairs at harder MCRs and finally listening for temporal patterns at the most difficult MCRs. Martin and Mussel (1979) found synthetic sentences could be identified on the basis of single word recognition.

Strategies reported by present subjects included trying to ignore the competitor, listening for one word, listening for particular phonemes, and listening for sequential patterns of the sentences. Certainly, the status of almost all subjects changed from naive to experienced by the end of the experimental procedure. Also, some subjects may have recognized reoccurring patterns of the primary message set toward the end of the testing procedure. The two retest sessions occurred following the eighth administration of the target sentences. Although previous experience suggested this type of learning effect developed sometime after the twelfth test presentation, it is possible that it occurred earlier.

The effect of learning on SSI test performance has been studied by Beattie and Clark (1982). They presented five synthetic sentences at each of six MCRs which varied in two dB steps from -6 dB to +4 dB for two trials (60 synthetic sentences), five synthetic sentences at each of four MCRs ranging from -2 dB to +4 dB during a third trial (20 synthetic sentences) and ten synthetic sentences at each of the original six MCRs for the fourth trial (60 synthetic sentences). Significant improvement in mean scores occurred between the first and

second trial for MCRs of 0 dB, +2 dB, and +4 dB while score improvement was delayed until the third trial for the -2 dB MCR value. Mean scores remained consistently low at MCRs of -6 dB and -4 dB for trials one, two, and four. In all instances the competitor was a four-talker complex. These results suggest that learning effect is greatest and occurs fastest at easier MCRs. It appears that subjects are initially confused by the competing speech message, even at favorable MCRs.

Another contributor to the relatively low test-retest reliability observed in this study was the use of the 50% performance level for administration of the retest. Thornton and Raffin (1978) found the greatest degree of subject variability near the 50% correct performance region for ten and 25-item speech discrimination tests. Theoretically, the 50% correct performance region of any psychometric function is inherently the most variable segment of the function. However, it is also the region in which performance is least affected by extremely difficult MCRs (low performance) or extremely easy MCRs (high performance). Test-retest reliability would be artifactually high if successive administrations involved MCRs where subjects performed near 0% or near 100% correct. Thus, the present test-retest correlation coefficients should be viewed as very conservative estimates of reliability. Less conservative and more complete estimates would be those based upon repeated measurement of the entire psychometric function.

Standard Error of the Mean. A relatively small numerical value for the SEM indicates clustering of individual scores about the group mean, independent of sample size. Mean SEM values for this study were

relatively small in numerical value and narrow in range (2.6 for DEN MT competing message to 3.8 for DEN MT + 1 competing message). This indicates there was close clustering of performance scores around group mean values which remain consistent across competing message conditions.

Reliability Indices of Other SSI Studies

Indices of reliability used in this study (odd-even, test-retest, SEM) have not been routinely used in other SSI studies. Four studies (Keith, 1977; Goldschmidt, 1979; Webb and Greenberg, 1980; and Beattie and Clark, 1982) did report standard deviations from which SEMs can be calculated. Goldschmidt (1979) was the only study that reported test-retest data. All of these studies employed normal listeners under earphones and a ten-item test. Beattie and Clark (1982) used a four-talker competing message while the other three used a single-talker competing message. Most SSI studies have ignored dispersion and reliability data entirely, reporting only mean performance scores as a function of MCR.

SEMs calculated for the four SSI studies reporting dispersion data were, in most cases, significantly larger than SEMs calculated for the present study. Mean SEMs collapsed across MCRs in the present study range from 2.6 to 3.6 for the six competing message conditions. The mean SEM across MCRs of -20, -10, and 0 dB for Keith's study was 5.3,. Webb and Greenberg's study yielded a mean SEM of 3.1 across MCRs of -24, -20, and -15 dB. Goldschmidt's data produced mean SEMs ranging from 6.1 to 6.6 for her six different single-talker competing message conditions. Finally, the mean SEM calculated for Beattie and

Clark's data across MCRs which produced scores from 20-80% correct (i.e., linear portion of psychometric function) was 3.9.

Dispersion data from this last study have particular relevance to the present study since both employed a continuous spectra competing speech message. The mean SEM of 3.2 calculated from MCRs within the linear portion of the psychometric function for the MT 8 competing message in the present study reflects less variance than Beattie and Clark's data under similar competing message conditions (continuous speech spectra). This reduced variance may be largely due to the use of a 25-item test in the present study rather than the ten item test employed by Beattie and Clark. According to Thornton and Raffin, the 95% confidence interval for a ten item test is significantly wider than the confidence interval of a 25-item test at any mean percent correct value. In other words, the 25-item test exhibits more measurement precision than the ten item test. More precise measurements produce less test variance.

Test-retest correlation coefficients in the present study were sporadic, ranging from -.33 to +.84 across six competing message conditions with a mean correlation coefficient of +.31. Test-retest measurements were taken at the MCR value which yields the closest to 50% correct score for each subject. Test-retest correlation coefficients obtained for a small number of subjects (N = 3) in Goldschmidt's study also varied significantly across six competing message conditions at MCRs of -12 and -18 dB. Correlation coefficients ranged from -.76 to +.56 with a mean of .0 at -12 dB MCR and from -.70 to +.99 with a mean of +.60 at -.18 dB MCR. Correlation coefficients obtained at the -24 dB MCR exhibited a smaller range (+.28 to +.99) across competing

message conditions and overall revealed high reliability with a mean of +.84. These data indicate that Goldschmidt obtained consistently high reliability only at the most difficult MCR.

One goal of this study was to reduce the variability of the SSI test. Examination of dispersion data (reflected by SEMs) indicates that score variance across subjects was reduced compared to previous SSI tests. Assessment of intra-list reliability suggests nothing in the experimental procedure systematically affected odd or even item performance. The status of test-retest reliability remains unclear, however. High test-retest reliability across experimental conditions either did not occur or was obscured by the method used to estimate it.

Psychometric Function Slope Values

A main objective of this study was to determine what effect (if any) semantic content has on SSI psychometric function slope values. Speaks, Karmen, and Benitez (1967) flattened the SSI psychometric function slope by using a single-talker competing message and attributed the effect to random masking (temporal discontinuity) and disruptive features (semantic content) inherent in the single-talker stimulus. The present study isolated the semantic content factor by controlling for temporal discontinuity and found no semantic content effect on SSI psychometric function slope values for any of the experimental conditions, except the single-ground competing message condition (MT 8). Here, the mean psychometric function slope of the multi-talker speech competitor indicated a steeper rather than flatter slope than its matched noise counterpart. It is questionable whether the multi-talker competing message slope was actually steeper than the

noise spectrum because of differences in the number of MCRs used to estimate the slopes for the respective competitors. It appears, however, that the speech stimulus (semantic content) slope was definitely not flatter than the slope of its associated noise stimulus (no semantic content).

Data from this study also corroborate findings of several other studies concerning the effect of competing message semantic content on SSI psychometric function slopes. Dirks and Bower (1969) found slopes of 4.0%/dB and 4.3%/dB for their single-talker competing message forward (CMF) and single-talker competing message backward (CMB) conditions. Trammel and Speaks (1970) discovered similar single-talker CMF and single-talker CMB slopes of 3.0%/dB and 2.4%/dB, respectively. Goldschmidt (1979) found a steeper CMF slope (3.8%/dB) than CMB (1.5%/dB) occurred between MCR values of -18 and -24 dB.

The present study also lends support to a study by Miller (1947) in which psychometric function slopes were obtained using a single-word target stimulus in the presence of various competing messages. Inspection of Miller's data reveals a multi-talker speech stimulus (eight voices) produced a slightly steeper psychometric function than a continuous spectrum masking noise. Psychometric function slopes for the multi-talker speech competing message and noise competing message were approximately 3.6%/dB and 3.0%/dB, respectively.

The psychometric function slopes determined in the present study range from 7.0%/dB to 8.5%/dB across competitor conditions and were much steeper than slopes obtained in the other studies using the single-talker competing message. The steeper slopes in the present study probably resulted from the continuous spectra of the competing

message. That is, competing messages exhibiting temporal discontinuity (i.e., single-talker). Data from Martin and Mussel (1979) support this contention. They found psychometric function slopes of approximately 4.6%/dB and 8.5%/dB for a single-talker competing message and a single-talker competing message mixed with white noise, respectively. The white noise added to the single-talker eliminated temporal discontinuity and increased psychometric function slope steepness. Webb and Greenberg (1980) noted their SSI psychometric function slope obtained with a four-talker competing message rose 11%/dB over the linear portion of the psychometric function.

In summary, the present study and several others support the contention that most (if not all) of the single-talker competing message flattening effect on the SSI psychometric function slope observed by Speaks, Karmen, and Benitez (1967) was caused by the temporal discontinuity factor (random masking) alone. Although it may generally be accepted that competing message semantic content does not affect the shape of the SSI psychometric function slope, the question of whether semantic content has an effect upon the location of the psychometric function along the abscissa is less well resolved. The present study sought to answer this question by comparing the masking efficiency of various competing messages.

Fifty-Percent Masking Efficiency Levels

The effect of competing message semantic content on masking efficiency was determined by analyzing the 50% masking efficiency levels of various competing message comparisons. One comparison examined competing message semantic content effect on 50% masking efficiency

levels in a single-ground, continuous spectrum competing message. Four other comparisons investigated competing message semantic content effect on 50% masking efficiency levels using various paris of foregorund-background competitors. The background of these competitors consisted of either multi-talker speech or multi-talker speech spectrum noise (modulated by the MT 8), whereas the foreground was either single-talker speech or single-talker speech spectrum noise (modulated by the single-talker). The relative amplitude level of the temporally discontinuous foreground in all foreground-background competing messages was 10 dB higher than that of the temporally continuous background, causing a 10 dB acoustic (perceptual) "window" during the foreground off-time. A final two analyses examined the effect of manipulating foreground semantic content status in temporally continuous speech and temporally continuous noise backgrounds, respectively. Several comparisons produced significant results.

Single-Ground Semantic Content. The MT 8 and DEN MT competing message comparison allowed examination of semantic content effect on 50% masking efficiency levels for single-ground temporally continuous competitors. The competing message stimuli in this comparison had equivalent acoustic parameters, which isolated the semantic content factor. Mean 50% masking efficiency levels of -11.4 dB and -14 dB for the MT 8 and DEN MT competing messages respectively were found to be significantly different. Thus, semantic content caused an excess in masking efficiency (perceptual masking) of 2.6 dB.

The existence of perceptual masking secondary to semantic content has been observed in two studies (Carhart, Tillman, and Greetis, 1969;

Carhart, Johnson, and Goodman, 1975) that have particular relevance to the present study. Carhart, Tillman, and Greetis (1969) investigated semantic content in continuous spectrum maskers using speech (single-talker) mixed with white noise and white noise alone as competing messages. Spondee thresholds were obtained in the presence of both competitors. They found 3.2 dB excess masking (perceptual masking) with the speech and white noise competing message compared to the white noise only competing message. The addition of a second talker to the white noise and single-talker competing message increased perceptual masking another 3.4 dB for a total of 6.6 dB excess masking. Carhart, Johnson, and Goodman (1975) also compared spondee thresholds obtained in the presence of (1) steady state speech spectrum noise (2) speech spectrum noise modulated by seven talker combinations, and (3) the seven talker combination (1, 2, 3, 16, 32, 64, and 128 voices). They discovered excesses in masking efficiency for all talker combinations relative to their respective associated modulated noise conditions. Masking efficiency increased to a maximum of 9.8 dB for the three-talker modulated noise speech spectrum, decreasing thereafter to stabilize at 3 dB with 64 talkers. Collectively, these studies indicate (1) semantic content causes perceptual masking (excess masking) when temporal discontinuity is either eliminated or controlled for, (2) perceptual masking increases with talker number until three talkers, and (3) perceptual masking decreases when four or more talkers are included in a competing message.

These findings agree with the findings of the present study that semantic content causes perceptual masking and also suggest that the amount of perceptual masking discovered in the present experiment may

have been greater if fewer talkers had been used in the multi-talker speech background (i.e., MT 3 instead of MT 8). Apparently, the inclusion of four or more talkers in a competing message reduces the intelligibility and therefore semantic content effect. Whereas one or two talkers in a competing message still allow the listener to take advantage of the peripheral "window" effect, four or more talkers in a competing message cause a reduction in the semantic content and a subsequent release from perceptual masking.

Evidently, as competing message phonemic images impinging upon the auditory nervous system become less distinct, (i.e., less like meaningful speech), the target speech stimuli become perceptually more distinct. This notion is supported by data from a study by Young, Parker, and Carhart (1975) which assessed digit recognition performance in the presence of forward speech (two and four talkers), backward speech (same two and four talkers) and speech modulated (same two and four talkers) speech spectrum noise. They found forward speech to be the most efficient masker, and backward speech second in masking efficiency, and speech modulated noise the least efficient masker. Again, as the masking agent became less speech-like, masking efficiency was reduced.

It could be that perceptual masking which occurs at the central level operates on a principle similar to physical masking at the peripheral level. According to the critical band theory, the most efficient masker of any particular tone is a narrow band of frequencies centered around that tone. If the narrow-band masker and target tone are analyzed in the same critical band along the basilar membrane of

the cochlea, masking efficiency will be increased compared to a situation where the masker and the target tone are analyzed in separate critical bands. Masking interference is greater when the target and masker stimuli are analyzed by common physical structures. Likewise, an excess in perceptual masking may occur at the central level when target and masker phonemic stimuli are mediated by common processes.

Experimental results reported by Triesman (1964) also have relevance to the MT 8 versus DEN MT comparison. Subjects in the Triesman study shadowed narrative extracts from a novel read in English by a female talker in the presence of several different competing messages. Subjects received a binaural presentation (presumably, diotic) of target and competing message stimuli. Competing message conditions pertinent to the present study include (1) same-voice, forward English speech, (2) same-voice, forward foreign speech, (3) same-voice, reversed speech and (4) different-voice (male), forward English speech. Treisman found (1) the lowest scores were obtained using the same-voice, forward English speech competing message, (2) intermediate scores were obtained using the same-voice, foreign speech and same-voice reverse speech competing messages, and (3) the highest scores occurred with the different-voice, forward English speech competing message. Triesman explained her findings that subjects performed poorer with the same-voice backward or same-voice foreign speech competing message than with different-voice (male) forward speech by suggesting that subjects were able to reject a competing message differing in physical features (man's voice) from the primary message (woman's voice) at an early stage in a perceptual analysis and thus better attend to the primary message. If

this early rejection on a physical basis cannot be made, then the ability to reject the competing message apparently depends on the degree of semantic content (meaning) in the competing message. Thus, the same-voice forward speech was much harder to reject than the same-voice foreign speech or same-voice backward speech.

Based on Triesman's findings, it would appear that subjects in the present study performed better with the DEN MT competing message than the MT 8 competing message because the former competing message (noise) was perceptually less like the target stimuli than was the latter competing message (speech). This allowed the subjects to more effectively reject the noise stimulus than the speech stimulus and better attend to the target sentences. Since the DEN MT and MT 8 had very similar physical characteristics (i.e., spectral and temporal characteristics) any difference in the ability of the auditory system to reject either stimulus probably did not occur at the most peripheral level (cochlea). It seems likely that differential rejection occurred later (more central) in the perceptual process on the basis of differences in the amount of psychological impact created by the two stimuli. The MT 8 competing message was harder to reject than the noise competing message because it caused psychological as well as physical interference. It is assumed that this occurred because the incoming speech competing message and target stimuli were analyzed by common neurological structures and processes.

Norman and Bobrow (1975) present a theoretical view of data-limited versus resource-limited psychological processing that has particular relevance to the present study. They define data-limited

processes as being constrained by input signal characteristics (e.g., physical masking) and resource-limited processes as being limited by available psychological resources (e.g., perceptual masking, attention, etc.). In a data-limited process performance is largely dependent upon the spectral and temporal characteristics of the input signal, whereas in a resource-limited process performance depends on the amount of psychological resources that can be allocated to a given task. It is important to note that resource-limited processes are not totally free from data-limitations because the peripheral mediation of the signal must occur prior to any central mediation. Performance on a data-limited task can be reduced by degradation of signal quality. Performance on a resource-limited task can be reduced by additional competition for limited psychological resources (auditory processing capabilities, linguistic knowledge, attention, etc.). Since the MT 8 and DEN MT competing messages are equivalent in the data sense, the more efficient masking ability of the MT 8 competing message must be due to additional competition for psychological resources. Thus, the speech competing message interferes with the processing of the primary speech signal on a physical as well as psychological basis.

Semantic Content in Foreground-Background Competitors. Three paired competing message comparisons were analyzed to assess the effect of semantic content position within foreground-background competing messages on 50% masking efficiency levels. A fourth foreground-background competing message paired comparison allowed assessment of the effect of semantic content position and type on 50% masking

efficiency levels. A separate discussion of each comparison follows.

The MT 8 + DEN 1 versus DEN MT + DEN 1 comparison investigated semantic content effect in the background only of a foreground-background competing message. Both competing messages had a temporally discontinuous foreground void of semantic content, but differed in the presence versus absence of semantic content in a temporally continuous background. The MT 8 + DEN 1 competing message (background semantic content) produced 2.8 dB excess masking compared to the foreground-background competing message void of semantic content in both grounds. Both competing messages exhibited a 10 dB acoustic (perceptual) "window" during the foreground off-time. The results suggest the subjects were better able to utilize the 10 dB acoustic windows available in the foreground-background competing messages when semantic content was absent in both grounds. The DEN MT + 1 versus DEN MT + DEN 1 comparison assessed the effects of the presence versus absence of foreground semantic content in foreground-background competing messages featuring temporally continuous noise background. Interestingly, it was discovered that semantic content in a temporally discontinuous foreground (single-talker) did not produce the same amount of excess masking observed with the temporally continuous background semantic content in the previous comparison. The DEN MT + 1 produced only a negligible amount of excess masking (1.0 dB), which was not statistically significant. Evidently, the temporal discontinuity (acoustic windows) of the single-talker in the DEN MT + 1 competing message negated any excess in masking

secondary to semantic content. In other words, when the semantic content is temporally discontinuous in nature it does not manifest the same degree of masking efficiency as temporally continuous semantic content.

Perhaps this last comparison explains the findings of Dirks and Bower (1968) that foreward single-talker and backward single-talker competing messages were equivalent in masking ability when the former competing message contained semantic content and the latter did not. In the Dirks and Bower study the acoustic windows existing in the single-talker competing message probably were about 40 dB in depth (i.e., from single-talker peak amplitude to equipment noise floor level), compared to acoustic windows 10 dB in depth in the present study (i.e., from foreground peak amplitude to background average amplitude). However, both studies indicate that temporal discontinuity of the semantic content component create perceptual windows that void any excess masking due to semantic content. It is also possible that semantic content effect may have been nullified in the Dirks and Bower study by the intensive subject training procedure.

Whereas foreground temporally discontinuous competing message semantic content (DEN MT + 1) caused a negligible amount of perceptual masking and background temporally continuous competing message semantic content (MT 8 + DEN 1) caused a moderate amount of perceptual masking relative to their respective noise counterparts, semantic content present in both grounds of a competing message (MT 8 + 1) produced a remarkable 8.9 dB of perceptual masking compared to its noise counterpart void of semantic content in both grounds (DEN MT + DEN 1). The amount of perceptual masking tht occurred with the MT 8 + 1

competing message is especially noteworthy when compared to the amount of perceptual masking produced by the MT 8 + DEN 1 and DEN MT + 1 competitors (2.8 dB and 1.0 dB, respectively). All three competitors contained semantic content and a 10 dB acoustic window separating the foreground and background. However, when semantic content appeared in both grounds, subjects were unable to utilize the temporal discontinuity factor inherent in the single-talker foreground to negate or partially negate semantic content effect. This last statement is supported by the finding that mean 50% masking efficiency levels of the foreground-background MT 8 + 1 and single-ground MT 8 competing messages were nearly identical (-11.6 dB and -11.4 dB, respectively). Semantic content was present in both competitors while acoustic windows were present in the former and absent in the latter. However, the competing messages produced essientially equivalent amounts of perceptual masking. Apparently, when competing message semantic content exists in both grounds of a foreground-background competing message, the size of the windows must be increased before the central auditory nervous system is able to gain a perceptual advantage (i.e., negate semantic content effect). Presumably, this advantage would be realized using deeper windows (larger difference between relative amplitudes of foreground and background) "wider" windows (increased off-time of foreground), or both.

Several studies have measured the effect of changing competing message acoustic window size on word or sentence recognition. Miller (1947) varied the on-off time of continuous spectrum noise from 20% on to 100% on and found increasingly reduced performance on PB words as the noise on-time became greater. Martin and Mussel (1979)

eliminated acoustic windows in a single-talker competing message by adding white noise and found increased masking efficiency. They used synthetic sentences as the primary stimuli. Carhart, Tillman, and Greetis (1968) obtained spondee thresholds using a single-talker competing message, a single-talker competing message mixed with modulated noise, and a two-talker competing message. Spondee thresholds were 5.1 dB poorer when the noise was added to the single-talker and 8.0 dB poorer when the two-talker complex was used. This finding indicates that reduction of acoustic window size alone accounts for some increased masking efficiency, however, the effect is even stronger if semantic content is increased in conjunction with decreased acoustic window size. This supports the finding of the present study that the MT 8 + 1 is a more efficient masker than any of the other foreground-background competing messages. The size of the acoustic windows in all four competing messages is equivalent, however, the MT 8 + 1 has more semantic content.

Another explanation of the remarkable masking efficiency of the MT 8 + 1 competing message compared to the other foreground-background competitors is based on Norman and Bobrow's (1975) account of data-limited versus resource-limited processes. All foreground-background competing messages exhibit similar spectral and temporal characteristics, but differ in the amount and position of semantic content. By definition, spectral and temporal characteristics qualify as data-limited factors while semantic content qualifies as a resource-limited factor. The competing messages are equivalent in the data sense, but differ in their degrees of competition for

available psychological resources. Apparently, the existence of semantic content in both grounds of a foreground-background competing message creates significantly more competition for available psychological resources than the non-existence of semantic content or the existence of semantic content in just one ground. Thus, the MT 8 + 1 competing message is inherently a more efficient masker than the other foreground-background competing messages because it causes an equivalent amount of data interference in addition to an increased amount of resource interference.

The last foreground-background competing message pair allowed examination of the effect of semantic content position and type on 50% masking efficiency levels. The MT 8 + DEN 1 competitor consists of a temporally continuous speech background and a temporally discontinuous noise foreground while the DEN MT + 1 competing message is comprised of a temporally continuous noise background and a temporally discontinuous speech foreground. It was discovered that the MT 8 + DEN 1 competing message produced 1.8 dB more perceptual masking than the DEN MT + 1 competing message. Again, the key to increased masking efficiency is related to the temporal status of the semantic content. When semantic content is temporally continuous, masking efficiency is greater than when semantic content is temporally discontinuous. This is true even though the temporally discontinuous foreground semantic content was 10 dB higher (louder) than the temporally continuous background semantic content in the respective competitors.

The Effect of Changing Foreground Semantic Content Status. Two comparisons examine the effect of changing foreground status in

competing messages with temporally continuous speech and noise background, respectively. Manipulation of foreground status included (1) adding a single-talker to the temporally continuous background (2) adding a single-talker speech modulated noise (DEN 1) to the temporally continuous background, and (3) elimination of the foreground. In the last condition the competitors actually became single-ground stimuli.

The first analysis revealed significant differences in the mean 50% masking efficiency levels obtained using MT 8, MT 8 + 1, and MT 8 + DEN 1 competing messages. Subsequent use of Tukey's test for specific comparisons determined the MT 8 + DEN 1 competing message mean 50% masking efficiency level (-17.7 dB) differed from MT 8 and MT 8 + 1 competing messages mean 50% masking efficiency levels, but levels of the latter two did not differ from each other (11.6 dB and 11.4 dB, respectively). Again, this finding confirms earlier results indicating subject inability to effectively utilize the 10 dB acoustic window in a foreground-background competing message when semantic content appears in both grounds.

The DEN MT, DEN MT + 1 and DEN MT + DEN 1 comparison also revealed significant differences in mean 50% masking efficiency levels among competitors. Tukey's test of specific comparisons found masking efficiency of the DEN MT 9-14.0 dB) differed from DEN MT + 1 and DEN MT + DEN 1 masking efficiency levels, whereas masking efficiency of the latter two were similar (-19.5 dB and -20.5 dB, respectively). Here, temporal characteristics of the masking spectrum appear to account for increased masking efficiency of the DEN MT competing message. Interestingly, the temporally continuous noise spectrum void

of semantic content is a more efficient masker than the spectrum consisting of the same noise stimulus (DEN MT) used in a background mode and coupled to a temporally discontinuous single-talker foreground. In the first instance, the temporal consistency and frequency composition of the masking spectrum more adversely affects central auditory nervous system processing,while in the latter instance the perceptual advantage gained by the 10 dB acoustic window manifests itself as semantic content occurs only in a temporally discontinuous foreground. These findings provide additional evidence that semantic content must appear in both grounds of a foreground-background competing message to eliminate the acoustic window effect.

CLINICAL IMPLICATIONS

The traditional SSI test has already been used as a clinical tool in the differential diagnosis of central auditory nervous system (CANS) disorders (Jerger and Jerger, 1974; Speaks, 1975; and Jerger and Jerger, 1975a and b). The SSI test material and competing messages used in the present study represent an improvement over the traditional 10 item test and the single-talker competing message. The 25-item test and continuous spectra stimuli served to reduce subject variability and increase test reliability. The eight alternative lists may serve to reduce learning effects associated with several administrations of the test.

Evidence from the present study suggests the MT 8 and MT 8 + 1 competing message cause more perceptual masking than the traditional single-talker competing message and thus may be more effective in identifying pathological conditions within the CANS. Pathological

conditions may result from the aging process, stroke, space occupying lesions, or trauma. The SSI test used in the present study may be effective in identifying these pathologies and in monitoring improvement in central auditory processing abilities following any medical intervention. For stroke and trauma victims, periodic testing throughout the therapeutic process may provide prognostic as well as diagnostic information. Pre-operative and post-operative testing of patients undergoing surgery to remove tumors within the CANS could provide information regarding the success of the operation.

The test could be applied to any literate population capable of understanding the task. The response mode (circling the correct item) could be modified for individuals with handicapping conditions that preclude marking ability. Test results should provide the clinician with reliable and valid indicators of an individual's auditory processing skills.

The SSI test used in this study in the present form would probably not be useful in testing young learning disabled (LD) children. Although use of the multi-talker competing message would be very appropriate in identifying a weak or underdeveloped CANS, the synthetic sentences may be too difficult for the LD children to comprehend and recall. The identification of a synthetic sentence on the response sheet requires reading skills LD children may not have. Relatively easy to understand and recall primary stimuli such as sentences used by Willeford (1977) or Central Institute for the Deaf everyday sentences may be more appropriate for this clinical population. It would also be necessary to establish chronological age group means for children with normal auditory processing skills before an adapted

version of the present SSI test would be useful in identifying children with poor auditory skills.

IMPLICATIONS FOR FUTURE RESEARCH

Before the present SSI test can be employed with an adult clinical population, a clinical test procedure must be defined. Additional research is needed to determine which competing messages and MCRs most effectively differentiate between normal and impaired CANSs. Presumably, the MT 8 competing message presented at a MCR which normal-hearing subjects score 70-80% (-8 dB) would provide the most useful diagnostic information. Extremely easy or extremely difficult MCRs would render the SSI test insensitive to the identification of pathological CANSs. Easy MCRs would not tax even an impaired system while difficult MCRs cause low performance scores for normal neurological systems. However, this needs to be verified. Another possible clinical procedure would involve adjusting the MCR until a 50% correct response rate is obtained. This adaptive procedure was used by Dirks, Morgan, and Dubno (1982) to determine the MCR at which normal and hearing-impaired listeners obtained 50% correct. The adaptive procedure effectively differentiated between normal and hearing-impaired subjects' ability to recognize spondees and monosyllables in the presence of speech babble. The adaptive method may also be effective in quickly identifying impaired CANSs. Normative as well as clinical (pathological) data must then be collected using the defined clinical testing procedure.

The MT 8 competing message used in the present study could also be used in the auditory assessment of LD children. However, as noted

in the previous section, this would require development of alternative primary stimuli and scoring procedures. Again, it would be necessary to develop a clinical procedure that differentiates between children with normal auditory processing abilities and children with reduced auditory processing abilities. It would also be necessary to collect data on normal and LD children.

Future research might deal with more experimental issues such as the size of the acoustic window in the foreground-background competing messages, especially the MT 8 + 1 competing message. It may be of interest to vary the depth or width of the acoustic window in this competitor and measure the effect. For example, the single-talker competing message (foreground) could be time-expanded in specified amounts for several experimental conditions. Time-expansion of the single-talker competing message would also expand the width of acoustic windows. It would then be possible to determine how much expansion (in percent) is necessary before normal CANSs can successfully negate the excessive semantic content effect inherent in the MT 8 + 1 competing message (i.e., MT 8 + 1 scores = DEN MT + DEN 1 scores at same MCR). The length of the acoustic windows could also be increased by reducing the single-talker speaking rate. The effect of increasing acoustic window depth could be studied by systematically lowering the background (multi-talker) amplitude.

Another focus of future research might entail changing the amount of semantic content in either the competing messages or the primary stimuli. Competing message semantic content could be varied by making the competing message more or less intelligible (increasing or decreasing talker number) or by stringing together semantically

unrelated phrases or sentences in the competitor. Synthetic sentence semantic content could be manipulated by using successive order approximations to real sentences (i.e., first order, second order, third order, etc.).

The SSI test developed for this study could be applied in several clinical or experimental endeavors. Various aspects of the test may need to be modified to accommodate different clinical populations or to answer different experimental questions. However, use of the 25-item four-alternative forced-choice response paradigm, continuous spectra competing messages, and precisely calibrated acoustic stimuli should serve to reduce subject variability and increase test reliability in any application.

CHAPTER V

SUMMARY AND CONCLUSIONS

INTRODUCTION

The SSI test allows assessment of an individuals ability to identify syntactically constrained sentential stimuli without the problems inherent in the use of real sentence stimuli (Speaks and Jerger, 1965). The traditional SSI test includes use of a ten-alternative closed message set and a single-talker competing message. Several studies (Dirks and Bower, 1969; Garstecki and Mulac, 1974; Trammell and Speaks, 1978; and Goldschmidt, 1979) have investigated the effect of competing message semantic content on SSI performance by comparing competing message foreward and competing message backward scores and found conflicting results. Several methodological differences which may have accounted for the discrepancy in results include differences in test stimuli, levels of subject sophistication, response modes, and presentation modes. Another reason for conflicting results may have been the high level of test variability reported in Goldschmidt's study. High test variability may be due to the use of a small ten-item test (Thorton and Raffin, 1978; and Raffin and Shafer, 1980) and the temporal discontinuity inherent in the single-talker competing message. Several studies (Miller, 1947; Carhart, Tillman, and Greetis, 1968; 1969; Speaks, Wigginton, and Germono, 1971; Carhart, Johnson, and Goodman, 1975; Young, Parker, and Carhart, 1975; and

Martin and Mussel, 1979) have reduced or eliminated competing message temporal discontinuity and found a clear semantic content effect on speech intelligibility scores using a variety of primary stimuli and competing messages. No one has studied the effect of competing message semantic content on SSI psychometric function slopes or 50% masking efficiency levels using acoustically identical speech and noise competitors. Also, no one has examined semantic content effect in foreground-background competing messages.

PURPOSE

The purpose of this study was to obtain SSI performance scores for normal-hearing subjects as a function of MCR for six different competing messages. Two dependent variables, psychometric function slope values and 50% masking efficiency levels, were interpolated from individual subject data. These dependent variables allowed direct comparison of the six competing messages on SSI performance. A 25-item test was employed to reduce subject variance.

EXPERIMENTAL DESIGN

Subjects

Thirty-six normal-hearing adult subjects were used in this study. Each subject displayed normal sensitivity for pure tones, spondees, acoustic reflexes, as well as normal reflex decay, middle ear function, and word discrimination scores. Twelve subjects were randomly assigned to each of three experimental groups.

Stimuli

Synthetic Sentences. Three hundred third-order synthetic sentences were generated for this study. One hundred and four synthetic

sentences met linguistic criteria employed by a three-judge panel. These synthetic sentences were recorded and measured for duration and relative amplitude. Twenty-seven synthetic sentences had durations within 100 m/sec of the mean duration and relative amplitudes within 0.5 dB of the mean relative sentence level. Twenty-five of these sentences were randomly chosen and used for target sentences. Different random orders of the 25 sentences were re-recorded on each of eight cassette test tapes. The 77 synthetic sentences that met the linguistic criteria, but did not meet the duration or amplitude criteria were used as distractor sentences in eight different SSI lists. Each of the eight lists exhibited a target sentence order that corresponded to the presentation order on one of the eight cassette tapes. Three distractor synthetic sentences were randomly combined with one target synthetic sentence for each of the 25-items on all eight lists. No two sentences within a four-alternative test item could begin or end with the same word or phoneme. Target sentence position was counterbalanced within each test item for all eight lists.

Competing Messages. This study employed two classes of competing messages; single-ground and foreground-background. Two competing messages were used to determine semantic content in continuous spectrum single-ground stimuli. Four other competing messages allowed examination of semantic content effect in foreground-background competing messages having a temporally continuous background and a temporally variable foreground. The single-ground competing messages were (1) multi-talker speech consisting of eight equally intense talkers and (2) speech spectrum noise derived from and modulated by the multi-talker stimulus. The foreground-background competing messages

included (1) the multi-talker background coupled with a single-talker foreground, (2) the multi-talker speech modulated noise background plus the single-talker speech modulated noise foreground, (3) the multi-talker background with the speech modulated noise foreground, and (4) the multi-talker speech modulated noise background combined with the single-talker foreground. A 10 dB difference in relative amplitude separated the background and foreground in these competing messages, thus creating a 10 dB acoustic window during foreground off-time. The two single-ground competitors had nearly identical physical characteristics while the four foreground-background competing messages were alwo nearly identical to each other in physical characteristics. This allowed isolation of the semantic content variable across competing message conditions.

PROCEDURE

The experimental procedure for each subject in this study included (1) signing a release-consent form, (2) undergoing a hearing screening, (3) participation in a practice session, and (4) completion of the main experiment.

During the practice session, each subject listened to five non-experimental synthetic sentences presented to the test ear at 40 dB SL in quiet to gain experience with the four-alternative forced-choice test paradigm. Eighteen other non-experimental synthetic sentences were then presented at 40 dB SL with the competing message adjusted to obtain a -2 dB MCR to provide the subjects with nine listening experiences with each of the two competing message conditions according to group assignment. The subjects task for each of the 23

items was to listen for the presentation and choose the correct answer on the response sheet. All subjects scored 100% on the practice test.

In the experimental session, each subject listened monaurally to a 25-item test list at each of four MCRs for both competing messages. The target stimuli were presented at a constant 40 dB SL and the intensity levels of the competing messages were varied. Again, the subject's task was to listen to each presentation and circle the correct answer on the response sheet. Retest data were obtained for both competing messages at the MCR which produced the nearest to 50% correct score for each subject.

FINDINGS

The experimental findings of the present study are as follows:

1. Mean monaural SSI psychometric function slope values obtained with normal listeners differed as a function of the presence versus absence of semantic content in a single-ground ipsilateral competing message. Mean psychometric function slope values were 8.5%/dB and 7.0%/dB for the MT 8 and DEN MT competing messages, respectively. However, this statement must be qualified by two considerations. First, the strength of association measure indicated only a trivial portion of the variance in slope could be attributed to the semantic content factor. Second, computation of the DEN MT slope was performed using three MCRs while the MT 8 slope was determined using four MCRs. Psychometric function slope values computed using mean scores at three corresponding MCRs revealed similar slopes (7.5%/dB for MT 8, 7.0%/dB

for DEN MT).

2. Mean monaural SSI psychometric function slopes obtained with normal-hearing listeners did not differ as a function of differences in foreground-background ipsilateral competing messages containing semantic content in:

a. Background only;

b. Foreground only, and

c. Background and foreground.

3. Mean monaural SSI psychometric function slopes obtained with normal-hearing listeners did not differ as a function of semantic content position and type in a foreground-background ipsilateral competing message (i.e., temporally continuous background semantic content versus temporally variable foreground semantic content).

4. Mean monaural SSI psychometric function slopes obtained with normal-hearing listeners did not differ as a function of differences in foreground status in ipsilateral competing messages containing a speech background.

5. Mean monaural SSI psychometric function slopes obtained with normal-hearing listeners did not differ as a function of differences in foreground status in ipsilateral competing messages containing a noise background.

6. Mean monaural 50% masking efficiency levels obtained with normal-hearing listeners differed as a function of the presence versus absence of semantic content in a single-ground ipsilateral competing message. Masking efficiency was 2.6 dB greater when semantic content was present.

7. Mean monaural SSI 50% masking efficiency levels obtained with normal-hearing listeners differed as a function of differences in foreground-background ipsilateral competing messages containing semantic content in the background only and both foreground and background. Background-foreground competing messages containing semantic content were more efficient maskers. Mean values did not differ as a function of semantic content in the foreground only.

8. Mean monaural SSI 50% masking efficiency levels obtained with normal-hearing listeners differed as a function of semantic content position and type in a foreground-background ipsilateral competing message. Masking efficiency was greater for the temporally continuous background semantic content competing message.

9. Mean monaural SSI 50% masking efficiency levels obtained with normal-hearing listeners differed as a function of differences in foreground status in an ipsilateral competing message containing a speech background. The noise foreground competing message exhibited reduced masking efficiency compared to the single-ground competing message and the speech foreground competing message. The latter two were similar in masking efficiency.

10. Mean monaural SSI 50% masking efficiency levels obtained with normal-hearing listeners differed as a function of differences in foreground status in an ipsilateral competing message containing a noise background. Greater masking efficiency was obtained with the single-ground competing message than with competing messages containing either a noise or speech foreground. The latter two were similar in masking efficiency.

11. Reliability (consistency) within experimental conditions was sporadic for the various competing messages as a function of MCR, using the odd vs. even procedure. The attainment of high reliability with this method depends on consistency at the individual subject level. Application of the binomial test yielded these scores which indicated equivalency between odd and even item performance for every experimental condition at the group level. The binomial test takes advantage of the "averaging out" that occurs at the group level and is not sensitive to odd and even item performance of individual subjects. Standard error of the mean values for the six competing messages all occurred within a narrow range indicating consistency across experimental conditions.

12. Test-retest performance scores were not consistent for any of the competing conditions except MT 8 + 1. Poor test-retest reliability was probably related to selection of the retest MCR value (near 50%) at which performance inherently variable. It is also likely that learning effects contributed to poor test-retest reliability.

CONCLUSIONS

In addition to the above findings, the following conclusions are offered.

1. Generally, ipsilateral competing messages containing semantic content (speech) and acoustically similar ipsilateral competing messages void of semantic content (noise) have an equivalent effect on normal-listener SSI psychometric function slope values. The various competing messages exhibited slope values within a narrow

range from 7.0%/dB to 8.5%/dB.

2. Competing messages containing semantic content caused physical masking at the peripheral level related to their spectral, amplitude, and temporal characteristics and perceptual masking at the central level related to their ability to interfere with psychological processing (i.e., linguistic processing).

3. The perceptual advantage gained by acoustic windows in foreground-background competing messages is partially reduced when semantic content occurs in the temporally continuous background only and completely negated when semantic content occurs in both the temporally continuous background and temporally discontinuous foreground. However, the perceptual advantage remains when semantic content occurs only in the temporally discontinuous foreground.

4. The 25-item four-alternative forced-choice SSI test paradigm coupled with the use of a temporally continuous competing message served to increase the precision of measurement in the present study compared to previous SSI studies. The present SSI test can be a useful clinical tool following collection of normative data.

APPENDIX A

APPENDIX A. SUBJECT SCREENING FORM

Project Name _____ Sub. No. _____

Name _____ Age ____ Examiner _____

Date _____

PURE TONE AIR CONDUCTION

					R / L	+ Pass HTL = 15 dB - Fail
250	500	1000	2000	4000		Coding

_____
Audiometer

ACOUSTIC REFLEX

	500 Hz	1000 Hz	2000 Hz	R. Decay	
Test Tone R / Tone Test L	HL	HL	HL	HL	+ Pass = 100 dB - Fail ARD + = 10 s
	HL	HL	HL	HL	

_____
Audiometer

TYMPANOMETRY

Pressure mm H_2O	Max. cc pt. (P)	(cc)	+200	+100	0	-100	-200	
Compliance cc	R / L	R / L	R / L	R / L	R / L	R / L	R / L	

_____
Impedance Bridge

SPEECH TESTING

SRT	NU-6	
R / L	R / L	+ Pass = SRT 15 dB HTL or less + Pass = 90 % or higher

HISTORY

Currently active URI? _____

Family History of Hearing Loss? _____

History of Tinnitus or Vertigo? _____

APPENDIX B

APPENDIX B. EIGHT SSI TEST LISTS

SSI LIST - FORM A

1. a. FEW YARDS TILL HEALTH STORES WARM PRESSES
   b. LAST IN BODY MOVEMENT THE SWEET MONEY
   c. SCENE TODAY GROWS LONG QUITE TRUE WITHIN
   d. UNDER ICE FOR FISH ESCAPE BEYOND WAR

2. a. TO OBJECT WHILE SHE COULD CLEAR ENOUGH
   b. MUST ACT BUSY TOMORROW AND STOP FOR
   c. CLEAR FROM CLOUDS ABOVE EARTH OPENS WIDE
   d. CHILDREN TOO SPOKE LAST BECAUSE SEVEN MILES

3. a. HEAVY LADIES THINK PRACTICE KEPT WHO DEALS
   b. MORE CLOTHES HAD NEVER CHANGED MEMBERS THAT
   c. WHILE UNDER NINE BIG MEETINGS BELONG KNOWN
   d. BEDS CAN'T KNOW MUSIC AS POST CHIEF

4. a. HEAT SEEMS DIFFERENT SINCE GOOD MANNERS CAN'T
   b. TAKE OUT WHOLE NUMBERS ALWAYS WENT AWAY
   c. CEASE CHANGE WEAR DRESSES WHILE LISTENING MADE
   d. EGGS GROWING CLOSE PRETTY CLEAN SNOW LIES

5. a. LIE AMONG THOSE WILD COUNTRY GARDEN BURNED
   b. CENTS SOMETIMES KEEP BETWEEN WIDE ENOUGH SHOES
   c. PLEASURE SIMPLE FRIEND GOT WHAT ALL NINE
   d. WATER FISH UNTIL NEXT SET IS LIKE

6. a. OVER BUILDING WALK HARD LIKE WOOD ON
   b. CLOTHES ACCOUNT NEARLY PAYS YOUR BOY CANNOT
   c. ALTHOUGH GROUPS TALK LATE YET MOST MAKE
   d. WERE PLEASANT WHILE WARM DAYS ACCOUNT FOR

7. a. FOR WHOM MOST SPARE MILLIONS SAFELY WATCH
   b. GROUPS BE COMMON WHILE UNDER STREAMS BUILDING
   c. CLEAN THROUGH PAPER WHICH PROMISES ME GREAT
   d. IS CUT LAST WEEK SOON GAVE PRACTICE

8. a. ALREADY TOOK COMMON WANTS OLD TRUTH KEPT
   b. WHILE LESS CLOSE EXCEPT BELOW WHITE GARDENS
   c. PEACE SEEMS KNOWN SPIRITS MET LITTLE SINGING
   d. SEEM YOUNG HOWEVER SEND STRAIGHT AWAY FROM

9. a. NEWS PLEASED EIGHT GIRLS UNDER BOXES PREPARE
   b. SHORT HUMAN HAIR FLIES GOING TILL THAN
   c. GUARDS SPRINGING WHILE HANGING WHERE WEIGHT TIES
   d. COUNTRY LED WAR OF MUSIC DANCED ALL

FORM A (Cont.)

10. a. STILL PLEASED SINCE COMING OUTSIDE STORES BUILD
    b. MORE HILLS LAY VILLAGES MILES WON'T PART
    c. COMPLETE HIS MOVEMENT ARRIVES NEAR SCHOOL ON
    d. GOVERNMENT POSTS YOUR PAIR TOOK WALKS FOR

11. a. DON'T WRITE LIKE STONE WILL GIVE PLEASURE
    b. WENT STRANGE QUICKLY MADE SEVEN TRAINS WON'T
    c. PEACE AROUND EARTH WON'T CARE PAST DANCING
    d. EXPLAINS SOMETHING WE WATCH OIL PROBLEMS FELL

12. a. NORTH PAST A BANK REMAINS ABLE TO
    b. SAVE SOULS NEARLY LOST INSIDE FUTURE PAIR
    c. DAY SAVE DOGS IN BROWN ONLY ACCORDING
    d. COOKS HEAT ALMOST TWO WORDS PREPARED BEFORE

13. a. WAIT EASY UNTIL TAKEN MORE SCHOOLS OUGHT
    b. THESE ESCAPE CLASSES INSTEAD SAVE TREES TILL
    c. CROWDS WHEN NONE TURNS SUCH HAPPY COMPANY
    d. SOON CAN WALK FAST EXCEPT BUILDING A

14. a. LIKE CERTAIN ROOMS EXPRESS HER VOICE OUGHT
    b. AMONG ACROSS THE BACK STORE ICE IN
    c. DARES NOT SERVE COMPLETE AMOUNTS FEEL CROSSES
    d. MILES WHILE QUICKLY SING OUTSIDE IN HONOR

15. a. ALTHOUGH WOOD ACTS GAIN ALL VIEWING FUTURE
    b. FOODS BUILD STRAIGHT TODAY SHOT SIX TREES
    c. EARTH ON SO HEAT ALLOWS FAMOUS HAT
    d. TAKE ANYTHING ABOVE CLOUDS SEE BRIGHT WHILE

16. a. ALTHOUGH DEEP RED COALS JUST NEEDS LONG
    b. SMALL TRIPS WON'T BUY BROKEN LIGHT NEXT
    c. LAY SUCH FEAR PAID A HEAVY PURPOSE
    d. FELL EIGHT YARDS SHOULD TURN SOMETHING SMOKE

17. a. IF BROKEN MEN ADD WATER EVEN TO
    b. TASTES GREAT DURING DEATH RATHER BREAK WATER
    c. SHIPS UNDER TALL METHODS REACH ABOVE REAL
    d. WARM DAYS MOVE WHILE FAVORS DON'T LET

18. a. CANNOT FIT SHOES FAST RATHER LOSE AFTER
    b. THOUGH WORTH DOLLARS IF SUCCESS MUST WAIT
    c. BEHIND BUT JOY OF PUBLIC LAND SOMETIMES
    d. SINCE GUARD SOLDIERS OF CONTROL KEEP BEAUTY

FORM A (Cont.)

19. a. SAFE IF BETWEEN EARTH ITS WILD HOW
    b. ICE FINALLY STOPPED EIGHT STATES VALUE OF
    c. UNDER NONE BURNED FINE NEARLY SINCE COLD
    d. DOLLARS WARY HAND FREE HOLD YOUR PRETTY

20. a. GAMES THAT BEING PAST YOUR VILLAGE FOLLOW
    b. REAL GIRLS KEEP LESS CHANCE RESULTS CONSIDER
    c. BROTHER PAID BRIGHT MUSIC DOUBLED IN SCHOOL
    d. MONEY WENT STRAIGHT HOURS WERE MOVING ALONE

21. a. EGGS SEVEN DRY CARS GATHERED SUCH FLOWERS
    b. HANG HEAVY BUT WHY UNTIL AN ARMY
    c. DURING SERVICE FEELS WRONG TILL IT PRESSED
    d. FAIR SENSE EXCEPT ITSELF SPREADS WEST UNTIL

22. a. ACROSS WHILE COMING FOR NONE WATCH FULL
    b. NOT TOWARD WINDOWS NEAR CHAIRS THUS ARE
    c. SINGLE FINE SEEMS WITH WEIGHT HANGING LOTS
    d. SHOP BEST DURING PARTIES THEIR YEAR NEARLY

23. a. WEST TILL LIFTING CLUBS KILLED BIRDS BEHIND
    b. NORTH BELOW THOSE TREES SHADE FARM PROVIDES
    c. SUMMER SHOULD DANCE SOON AMONG BOOKS BURN
    d. HURTS BEYOND LONG REACH IS EASY TILL

24. a. DIRECTS MARKET OF VALUE CAME FIVE DAYS
    b. YET CAUGHT WIND FIRST BECOMES JUDGE ABLE
    c. SHOULD SIT UNDER WATER WORLD LEADS AGAINST
    d. JUST MODERN OPINIONS STAY CLEAR NOT WILD

25. a. VALLEY OFTEN GREW WISE LAST HOUR WENT
    b. SAFE IF BETWEEN EARTH ITS WILD NOW
    c. AND WAIT THREE COMMANDS MUST MEET CLOSE
    d. DOLLARS WARY HAND FREE HOLD YOUR PRETTY

SSI LIST - FORM B

1. a. GOVERNMENT POSTS YOUR PAIR TOOK WALKS FOR
   b. IF BROKEN MEN ADD WATER EVEN TO
   c. EGGS SEVEN DRY CARS GATHERED SUCH FLOWERS
   d. WAIT EASY UNTIL TAKEN MORE SCHOOLS OUGHT

2. a. CENTS SOMETIMES KEEP BETWEEN WIDE ENOUGH SHOES
   b. FAIR SENSE EXCEPT ITSELF SPREADS WEST UNTIL
   c. MUST ACT BUSY TOMORROW AND STOP FOR
   d. CLEAR FROM CLOUDS ABOVE EARTH OPENS WIDE

3. a. PEACE AROUND EARTH WON'T CARE PAST DANCING
   b. CROWDS WHEN HOME NONE TURNS SUCH HAPPY COMPANY
   c. AND WAIT THREE COMMANDS MUST MEET CLOSE
   d. NORTH PAST A BANK REMAINS ABLE TO

4. a. LAST IN BODY MOVEMENT THE SWEET MONEY
   b. WARM DAYS MOVE WHILE FAVORS DON'T LET
   c. SUMMER SHOULD DANCE SOON AMONG BOOKS BURN
   d. ACROSS WHILE COMING FOR NONE WATCH FULL

5. a. GROUPS BE COMMON WHILE UNDER STREAMS BUILDING
   b. TASTES GREAT DURING DEATH RATHER BREAK WATER
   c. MONEY WENT STRAIGHT HOURS WERE MOVING ALONE
   d. HEAVY LADIES THINK PRACTICE KEPT WHO DEALS

6. a. HANG HEAVY BUT WHY UNTIL AN ARMY
   b. YET CAUGHT WIND FIRST BECOMES JUDGE ABLE
   c. ALTHOUGH DEEP RED COALS JUST NEEDS LONG
   d. WHILE LESS CLOSE EXCEPT BELOW WHITE GARDENS

7. a. UNDER ICE FOR FISH ESCAPE BEYOND WAR
   b. PEACE SEEMS KNOWN SPIRITS MET LITTLE SINGING
   c. VALLEY OFTEN GREW WISE LAST HOUR WENT
   d. LAY SUCH FEAR PAID A HEAVY PURPOSE

8. a. MILES WHILE QUICKLY SING OUTSIDE IN HONOR
   b. SHORT HUMAN HAIR FLIES GOING TILL THAN
   c. STILL PLEASED SINCE COMING OUTSIDE STORES BUILD
   d. BROTHER PAID BRIGHT MUSIC DOUBLED IN SCHOOL

9. a. REAL GIRLS KEEP LESS CHANCE RESULTS CONSIDER
   b. BEHIND BUT JOY OF PUBLIC LAND SOMETIMES
   c. WEST TILL LIFTING CLUBS KILLED BIRDS BEHIND
   d. SMALL TRIPS WON'T BUY BROKEN LIGHT NEXT

SSI FORM B (Cont.)

10. a. THOUGH WORTH DOLLARS IF SUCCESS MUST WAIT
    b. GAMES THAT BEING PAST YOUR VILLAGE FOLLOWS
    c. NOT TOWARD WINDOWS NEAR CHAIRS THUS ARE
    d. FEEL EIGHT YARDS SHOULD BURN SOMETHING SMOKE

11. a. TAKE ANYTHING ABOVE CLOUDS SEEM BRIGHT WHILE
    b. JUST GLAD DIFFERENT VALUES TEACH MINDS QUITE
    c. NEWS PLEASED EIGHT GIRLS UNDER BOXES PREPARE
    d. UNDER NONE BURNED FINE NEARLY SINCE COLD

12. a. WENT STRANGE QUICKLY MADE SEVEN TRAINS WON'T
    b. THESE ESCAPE CLASSES INSTEAD SAVE TREES TILL
    c. FELL WHILE COLD SOFT BEINGS BUT THOUSANDS
    d. SAVE SOULS NEARLY LOST BESIDE FUTURE FAIR

13. a. ICE FINALLY STOPPED EIGHT STATES VALUE OF
    b. HEAT SEEMS DIFFERENT SINCE GOOD MANNERS CAN'T
    c. FOODS BUILD STRAIGHT TODAY SHOT SIX TREES
    d. JUST MODERN OPINIONS STAY CLEAR NOT WILD

14. a. COOKS ALMOST TWO WORDS PREPARED BEFORE
    b. SCENE TODAY GROWS LONG QUITE TRUE WITHIN
    c. LIE AMONG THOSE WILD COUNTRY GARDEN BURNED
    d. GUARDS SPRINGING WHILE HANGING WHERE WEIGHT TIES

15. a. EXPLAINS SOMETHING WE WATCH OIL PROBLEMS FELL
    b. MORE HILLS LAY VILLAGES MILES WON'T PART
    c. ALTHOUGH WOOD ACTS GAIN ALL VIEWING FUTURE
    d. SHOP BEST DURING PARTIES THEIR NEAR NEARLY

16. a. DOLLARS WARY HAND FREE HOLD YOUR PRETTY
    b. FOR WON MOST SPARE MILLIONS SAFELY WATCH
    c. SEEM YOUNG HOWEVER SEND STRAIGHT AWAY FROM
    d. CLOTHES ACCOUNT NEARLY PAYS YOUR BOY CANNOT

17. a. TO OBJECT WHILE SHE COULD CLEAR ENOUGH
    b. AMOUNT ACROSS THE BACK STORE ICE IN
    c. CLEAN THROUGH PAPER WHICH PROMISES ME GREAT
    d. HURTS BEYOND LONG REACH IS EASY TILL

18. a. HOUSE EAST LAND YOURSELF DOWN WITH THOSE
    b. CEASE CHANGE WEAR DRESSES WHILE LISTENING MADE
    c. DAY SAVE DOGS IN BROWN ONLY ACCORDING
    d. BEDS CAN'T KNOW MUSIC AS POST CHIEF

19. a. IS CUT LAST WEEK SOON GAVE PRACTICE
    b. TAKE OUT WHOLE NUMBERS ALWAYS WENT AWAY
    c. SAFE IF BETWEEN EARTH ITS WILD HOW
    d. WATER FISH UNTIL NEXT SET IS LIKE

SSI FORM B (Cont.)

20. a. WERE PLEASANT WHILE WARM DAYS ACCOUNT FOR
    b. ALREADY TOOK COMMON WANTS OLD TRUTH KEPT
    c. SOON CAN WALK FAST EXCEPT BUILDING A
    d. NORTH BELOW THOSE TREES SHADE FARM PROVIDES

21. a. EGGS GROWING CLOSE PRETTY CLEAN SNOW LIES
    b. WHILE UNDER NINE BIG MEETINGS BELONG KNOWN
    c. MORE CLOTHES HAD NEVER CHANGED MEMBERS THAT
    d. CANNOT FIT SHOES FAST RATHER LOST AFTER

22. a. FEW YARDS TILL HEALTH STORES WARM PRESSES
    b. COMPLETE HIS MOVEMENT ARRIVES NEAR SCHOOL ON
    c. SHIPS UNDER TALL METHODS REACH ABOVE REAL
    d. CAN'T WRITE LIKE STONE WILL GIVE PLEASURE

23. a. COUNTRY LED WAR OF MUSIC DANCED ALL
    b. EARTH ON SO HEAT ALLOWS FAMOUS HAT
    c. DARES NOT SERVE COMPLETE AMOUNT FELL CROSSES
    d. PLEASURE SIMPLE FRIEND GOT WHAT ALL NINE

24. a. ALTHOUGH GROUPS TALK LATE MOST MAKE
    b. DURING SERVICES FEELS WRONG TILL IT PRESSED
    c. OVER BUILDINGS WALK HARD LIKE WOOD ON
    d. CHILDREN TOO SPOKE LAST BECAUSE SEVEN MILES

25. a. LIKE CERTAIN ROOMS EXPRESS HER VOICE OUGHT
    b. DIRECTS MARKET OF VALUE CAME FIVE WAVES
    c. SINCE GUARD SOLDIERS OF CONTROL KEEP BEAUTY
    d. TASTES GREAT DURING DEATH RATHER BREAK AFTER

SSI LIST - FORM C

1. a. YET CAUGHT WIND FIRST BECOMES JUDGE ABLE
   b. COMPLETE HIS MOVEMENT ARRIVES NEAR SCHOOL ON
   c. LIE AMONG THOSE WILD COUNTRY GARDEN BURNED
   d. HOUSE EAST LAND YOURSELF DOWN WITH THOSE

2. a. SAVE SOULS NEARLY LOST BESIDE FUTURE FAIR
   b. THESE ESCAPE CLASSES INSTEAD SAVE TREES TILL
   c. NEWS PLEASED EIGHT GIRLS UNDER BOXES PREPARE
   d. LAY SUCH FEAR PAID A HEAVY PURPOSE

3. a. CANNOT FIT SHOES FAST RATHER LOSE AFTER
   b. SEEM YOUNG HOWEVER SEND STRAIGHT AWAY FROM
   c. GUARDS SPRINGING WHILE HANGING WHERE WEIGHT TIES
   d. SHIPS UNDER TALL METHODS REACH ABOVE REAL

4. a. REAL GIRLS KEEP LESS CHANCE RESULTS CONSIDER
   b. CROWDS WHEN NONE TURNS SUCH HAPPY COMPANY
   c. GROUPS BE COMMON WHILE UNDER STREAMD BUILDING
   d. WATER FISH UNTIL NEXT SET IS LIKE

5. a. TAKE OUT WHOLE NUMBERS ALWAYS WENT AWAY
   b. WEST UNTIL LIFTING CLUBS KILLED BIRDS BEHIND
   c. EARTH ON SO HEAT ALLOWS FAMOUS HAT
   d. CLOTHES ACCOUNT NEARLY PAYS YOUR BOY CANNOT

6. a. NORTH PAST A BANK REMAINS ABLE TO
   b. ICE FINALLY STOPPED EIGHT STATES VALUE OF
   c. EARTH ON SO HEAT ALLOWS FAMOUS HAT
   d. LAST IN BODY MOVEMENT THE SWEET MONEY

7. a. UNDER ICE FOR FISH ESCAPE BEYOND WAR
   b. HANG HEAVY BUT WHY UNTIL AN ARMY
   c. PLEASURE SIMPLE FRIEND GOT WHAT ALL NINE
   d. MORE HILLS LAY VILLAGES MILES WON'T PART

8. a. EGGS SEVEN DRY CARS GATHERED SUCH FLOWERS
   b. WHILE UNDER NINE BIG MEETINGS BELONG KNOWN
   c. DOLLARS WARY HAND FREE HOLD YOUR PRETTY
   d. HURTS BEYOND LONG REACH IS EASY TILL

9. a. SCENE TODAY GROWS LONG QUITE TRUE WITHIN
   b. WERE PLEASANT WHILE WARM DAYS ACCOUNT FOR
   c. BROTHER PAID BRIGHT MUSIC DOUBLED IN SCHOOL
   d. HEAT SEEMS DIFFERENT SINCE GOOD MANNERS CAN'T

FORM C (Cont.)

10. a. IF BROKEN MEN ADD WATER EVEN TO
    b. ACROSS WHILE COMING FOR NONE WATCH FULL
    c. SHORT HUMAN HAIR FLIES GOING TILL THAN
    d. BEHIND BUT JOY OF PUBLIC LAND SOMETIMES

11. a. ALTHOUGH GROUPS TALK LATE YET MOST MAKE
    b. FOR WHOM MOST SPARE MILLIONS SAFELY WATCH
    c. DON'T WRITE LIKE STONE WILL GIVE PLEASURE
    d. EGGS GROWING CLOSE PRETTY CLEAN SNOW LIES

12. a. SAFE IF BETWEEN EARTH ITS WILD HOW
    b. UNDER NONE BURNED FINE NEARLY SINCE COLD
    c. HEAVY LADIES THINK PRACTICE KEPT WHO DEALS
    d. EXPLAINS SOMETHING WE WATCH OIL PROBLEMS FELL

13. a. MONEY WENT STRAIGHT HOURS WERE MOVING ALONE
    b. FEW YEARS TILL HEALTH STORES WARM PRESSES
    c. ALTHOUGH WOOD ACTS GAIN ALL VIEWING FUTURE
    d. WAIT EASY UNTIL TAKEN MORE SCHOOLS OUGHT

14. a. STILL PLEASED SINCE COMING OUTSIDE STORES BUILD
    b. COUNTRY LED WAR OF MUSIC DANCED ALL
    c. FELL WHILE COLD SOFT BEINGS BUY THOUSANDS
    d. DAY SAVE DOGS IN BROWN ONLY ACCORDING

15. a. DURING SERVICE FEELS WRONG TILL IT PRESSED
    b. TASTES GREAT DURING DEATH RATHER BREAK WATER
    c. AMOUNT ACROSS THE BACK STORE ICE IN
    d. MORE CLOTHES HAD NEVER CHANCED MEMBERS THAT

16. a. TO OBJECT WHILE SHE COULD CLEAR ENOUGH
    b. MUST ACT BUSY TOMORROW AND STOP FOR
    c. LIKE CERTAIN ROOMS EXPRESS HER VOICE OUGHT
    d. CLEAR FROM CLOUDS ABOVE EARTH OPENS WIDE

17. a. SOON CAN WALK FAST EXCEPT BUILDING A
    b. OVER BUILDINGS WALK HARD LIKE WOOD ON
    c. VALLEY OFTEN GREW WISE LAST HOUR WENT
    d. DIRECTS MARKET OF VALUE CAME FIVE WAVES

18. a. SINGLE FINE SEEMS WITH WEIGHT HANGING LOTS
    b. CLEAN THROUGH PAPER WHICH PROMISES ME GREAT
    c. ALTHOUGH DEEP RED COALS JUST NEEDS LONG
    d. MILES WHILE QUICKLY SING OUTSIDE IN HONOR

19. a. IS CUT LAST WEEK SOON GAVE PRACTICE
    b. BEDS CAN'T KNOW MUSIC AS POST CHIEF
    c. COOKS HEAT ALMOST TWO WORDS PREPARED BEFORE
    d. THOUGH WORTH DOLLARS IF SUCCESS MUST WAIT

FORM C (Cont.)

20. a. PEACE SEEMS KNOWN SPIRITS MET LITTLE SINGING
    b. FAIR SENSE EXCEPT ITSELF SPREADS WEST UNTIL
    c. GAMES THAT BEGIN PAST YOUR VILLAGE FOLLOWS
    d. WARM DAYS MOVE WHILE FAVORS DON'T LET

21. a. WHILE LESS CLOSE EXCEPT BELOW WHITE GARDENS
    b. JUST MODERN OPINIONS STAY CLEAR NOT WILD
    c. SMALL TRIPS WON'T BUY BROKEN LIGHT NEXT
    d. WHILE LESS CLOSE EXCEPT BELOW WHITE GARDENS

22. a. GOVERNMENT POSTS YOUR PAIR TOOK WALKS FOR
    b. NOT TOWARD WINDOWS NEAR CHAIRS THUS ARE
    c. FELL EIGHT YARDS SHOULD BURN SOMETHING SMOKE
    d. SHOULD SIT UNDER WATER WORLD LEADS AGAINST

23. a. CLEAR FROM CLOUDS ABOVE EARTH OPENS WIDE
    b. ALREADY TOOK COMMON WANTS OLD TRUTH KEPT
    c. SHOP BEST DURING PARTIES THEIR YEAR NEARLY
    d. FELL WHILE COLD SOFT BEINGS BUY THOUSANDS

24. a. TAKE ANYTHING ABOVE CLOUDS SEEM BRIGHT WHILE
    b. JUST GLAD DIFFERENT VALUES TEACHER MINDS QUITE
    c. FOODS BUILD STRAIGHT TODAY SHOT SIX TREES
    d. SINCE GUARD SOLDIERS OF CONTROL KEEP BEAUTY

25. a. CLEAR FROM CLOUDS ABOVE EARTH OPENS WIDE
    b. CENTS SOMETIMES KEEP BETWEEN WIDE ENOUGH SHOES
    c. WENT STRANGE QUICKLY MADE SEVEN TRAINS WON'T
    d. TO OBJECT WHILE SHE COULD CLEAR ENOUGH

SSI LIST - FORM D

1. a. VALLEY OFTEN GREW WISE LAST HOUR WENT
   b. IF BROKEN MEN ADD WATER EVEN TO
   c. COMPLETE HIS MOVEMENT ARRIVES NEAR SCHOOL ON
   d. FOODS BUILD STRAIGHT TODAY SHOT SIX TREES

2. a. NORTH BELOW THOSE TREES SHADE FARM PROVIDES
   b. HURTS BEYOND LONG REACY IS EASY TILL
   c. SAVE SOULS NEARLY LOST BESIDE FUTURE FAIR
   d. WATER FISH UNTIL NEXT SET IS LIKE

3. a. NOT TOWARD WINDOWS NEAR CHAIRS THUS ARE
   b. STILL PLEASED SINCE COMING OUTSIDE STORES BUILD
   c. ALONG MOVING WENT STRAIGHT HOURS WERE
   d. EGGS GROWING CLOSE PRETTY CLEAN SNOW LIES

4. a. BROTHER PAID BRIGHT MUSIC DOUBLED IN SCHOOL
   b. WHILE LESS CLOSE EXCEPT BELOW WHITE GARDENS
   c. MUST ACT BUSY TOMORROW AND STOP FOR
   d. UNDER NONE BURNED FINE NEARLY SINCE COLD

5. a. GUARDS SPRINGING WHILE HANGING WHERE WEIGHT TIES
   b. YET CAUGHT WIND FIRST BECOMES JUDGE ABLE
   c. DOLLARS WARY HAND FREE HOLD YOUR PRETTY
   d. CANNOT FIT SHOES FAST RATHER LOSE AFTER

6. a. MILES WHILE QUICKLY SING OUTSIDE IN HONOR
   b. TO OBJECT WHILE SHE COULD CLEAR ENOUGH
   c. HANG HEAVY BUT WHY UNTIL AN ARMY
   d. COUNTRY LED WAR OF MUSIC DANCED ALL

7. a. BEDS CAN'T KNOW MUSIC AS POST CHIEF
   b. FELL EIGHT YARDS SHOULD BURN SOMETHING SMOKE
   c. HEAVY LADIES THINK PRACTICE KEPT WHO DEAL
   d. EARTH ON SO HEAT ALLOWS FAMOUS HAT

8. a. UNDER ICE FOR FISH ESCAPE BEYOND WAR
   b. SHOP BEST DURING PARTIES THEIR YEAR NEARLY
   c. FELL WHILE COLD SOFT BEINGS BUY THOUSANDS
   d. CLOTHES ACCOUNT NEARLY PAYS YOUR BOY CANNOT

9. a. FOR WHOM MOST SPARE MILLIONS SAFELY WATCH
   b. ALTHOUGH DEEP RED COALS JUST NEEDS LONG
   c. JUST MODERN OPINIONS STAY CLEAR NOT WILD
   d. SMALL TRIPS WON'T BUY BROKEN LIGHT NEXT

FORM D (Cont.)

10. a. DAY SAVES DOGS IN BROWN ONLY ACCORDING
    b. COOKS HEAT ALMOST TWO WORDS PREPARED BEFORE
    c. WARM DAYS MOVE WHILE FAVORS DON'T LET
    d. SHORT HUMAN HAIR FLIES GOING TILL THAN

11. a. LIKE CERTAIN ROOMS EXPRESS HER VOICE OUGHT
    b. DON'T WRITE LIKE STONE WILL GIVE PLEASURE
    c. CROWDS WHEN NONE TURNS SUCH HAPPY COMPANY
    d. AMOUNT ACROSS THE BACK STORE ICE IN

12. a. WHILE UNDER NINE BIG MEETINGS BELONG KNOWN
    b. GAMES THAT BEGIN PAST YOUR VILLAGE FOLLOWS
    c. MORE CLOTHES HAD NEVER CHANCED MEMBERS THAT
    d. LIE AMONG THOSE WILD COUNTRY GARDEN BURNED

13. a. ALTHOUGH WOOD ACTS GAIN ALL VIEWING FUTURE
    b. SUMMER SHOULD DANCE SOON AMONG BOOKS BURN
    c. PEACE AROUND EARTH WON'T CARE PAST DANCING
    d. LAY SUCH FEAR PAID A HEAVY PURPOSE

14. a. CENTS SOMETIMES KEEP BETWEEN WIDE ENOUGH SHOES
    b. ALTHOUGH GROUPS TALK ALTE YET MOST MAKE
    c. JUST GLAD DIFFERENT VALUES TEACH MINDS QUITE
    d. WENT STRANGE QUICKLY MADE SEVEN TRAINS WON'T

15. a. OVER BUILDINGS WALK HARD LIKE WOOD ON
    b. SCENE TODAY GROWS LONG QUITE TRUE WITHIN
    c. EXPLAINS SOMETHING WE WATCH OIL PROBLEMS FELL
    d. HOUSE EAST LAND YOURSELF DOWN WITH THOSE

16. a. THOUGH WORTH DOLLARS IF SUCCESS MUST WAIT
    b. CEASE CHANGE WEAR DRESSES WHILE LISTENING MADE
    c. NEWS PLEASED EIGHT GIRLS UNDER BOXES PREPARE
    d. DARES NOT SERVE COMPLETE AMOUNTS FEEL CROSSES

17. a. SEEM YOUNG HOWEVER SEND STRAIGHT AWAY FROM
    b. GOVERNMENT POSTS YOUR PAIR TOOK WALKS FOR
    c. CLEAR FROM CLOUDS ABOVE EARTH OPENS WIDE
    d. PEACE SEEMS KNOWN SPIRITS MET LITTLE SINGING

18. a. SINGLE FINE SEEMS WITH WEIGHT HANGING LOTS
    b. WERE PLEASANT WHILE WARM DAYS ACCOUNT FOR
    c. HEAT SEEMS DIFFERET SINCE GOOD MANNERS CAN'T
    d. DURING SERVICES FEELS WRONG TILL IT PRESSED

19. a. REAL GIRLS KEEP LESS CHANCE RESULTS CONSIDER
    b. LAST IN BODY MOVEMENT THE SWEET MONEY
    c. ALREADY TOOK COMMON WANTS OLD TRUTH KEPT
    d. SOON CAN WALK FAST EXCEPT BUILDING A

FORM D (Cont.)

20. a. IS CUT LAST WEEK SOON GAVE PRACTICE
    b. MORE HILLS LAY VILLAGES MILES WON'T PART
    c. DIRECTS MARKET OF VALUE CAME FIVE WAVES
    d. TAKE ANYTHING ABOVE CLOUDS SEEM BRIGHT WHILE

21. a. PLEASURE SIMPLE FRIEND GOT WHAT ALL NINE
    b. FAIR SENSE EXCEPT ITSELF SPREADS WEST UNTIL
    c. EGGS SEVEN DRY CARS GATHERED SUCH FLOWERS
    d. WATER FISH UNTIL NEXT SET IS LIKE

22. a. TASTES GREAT DURING DEATH RATHER BREAK WATER
    b. SHIPS UNDER TALL METHODS REACH ABOVE REAL
    c. BEHIND BUT JOY OF PUBLIC LAND SOMETIMES
    d. WAIT EASY UNTIL TAKEN MORE SCHOOLS OUGHT

23. a. SAFE IF BETWEEN EARTH ITS WILD HOW
    b. TAKE OUT WHOLE NUMBERS ALWAYS WENT AWAY
    c. THESE ESCAPE CLASSES INSTEAD SAVE TREES TILL
    d. ICE FINALLY STOPPED EIGHT STATES VALUE OF

24. a. SHOULD SIT UNDER WATER WORLD LEADS AGAINST
    b. GROUPS BE COMMON WHILE UNDER STREAMS BUILDING
    c. ACROSS WHILE COMING FOR NONE WATCH FULL
    d. NORTH PAST A BANK REMAINS ABLE TO

25. a. WEST TILL LIFTING CLUBS KILLED BIRDS BEHIND
    b. CLEAN THROUGH PAPER WHICH PROMISES ME GREAT
    c. AND WAIT THREE COMMANDS MUST MEET CLOSE
    d. SINCE GUARD SOLDIERS OF CONTROL KEEP BEAUTY

SSI LIST - FORM E

1. a. MUST ACT BUSY TOMORROW AND STOP FOR
   b. CENTS SOMETIMES KEEP BETWEEN WIDE ENOUGH SHOES
   c. BROTHER PAID BRIGHT MUSIC DOUBLED IN SCHOOL
   d. WATER FISH UNTIL NEXT SET IS LIKE

2. a. BEHIND BUT JOY OF PUBLIC LAND SOMETIMES
   b. ACROSS WHILE COMING FOR NONE WATCH FULL
   c. REAL GIRLS KEEP LESS CHANCE RESULTS CONSIDER
   d. IF BROKEN MEN ADD WATER EVEN TO

3. a. NORTH PAST A BANK REMAINS ABLE TO
   b. WHILE LESS CLOSE EXCEPT BELOW WHITE GARDENS
   c. HEAT SEEMS DIFFERENT SINCE GOOD MANNERS CAN'T
   d. ALTHOUGH WOOD ACTS GAIN ALL VIEWING FUTURE

4. a. CANNOT FIT SHOES FAST RATHER LOSE AFTER
   b. FAIR SENSE EXCEPT ITSELF SPREADS WEST UNTIL
   c. CROWDS WHEN NONE TURNS SUCH HAPPY COMPANY
   d. WEST TILL LIFTING CLUBS KILLED BIRDS BEHIND

5. a. OVER BUILDINGS WALK HARD LIKE WOOD ON
   b. GROUPS BE COMMON WHILE UNDER STREAMS BUILDING
   c. NEWS PLEASED EIGHT GIRLS UNDER BOXES PREPARE
   d. SEEM YOUNG HOWEVER SEND STRAIGHT AWAY FROM

6. a. SINGLE FINE SEEMS WITH WEIGHT HANGING LOTS
   b. YET CAUGHT WIND FIRST BECOMES JUDGE ABLE
   c. WHILE UNDER NINE BIG MEETINGS BELONG KNOWN
   d. TAKE OUT WHOLE NUMBERS ALWAYS WENT AWAY

7. a. MONEY WENT STRAIGHT HOURS WERE MOVING ALONE
   b. CLEAR FROM CLOUDS ABOVE EARTH OPENS WIDE
   c. TASTES GREAT DURING DEATH RATHER BREAK WATER
   d. IS CUT LAST WEEK SOON GAVE PRACTICE

8. a. CLOTHES ACCOUNT NEARLY PAYS YOUR BOY CANNOT
   b. DON'T WRITE LIKE STONE WILL GIVE PLEASURE
   c. SOON CAN WALK FAST EXCEPT BUILDING A
   d. DIRECTS MARKET OF VALUE CAME FIVE WAVES

9. a. WENT STRANGE QUICKLY MADE SEVEN TRAINS WON'T
   b. NORTH BELOW THOSE TREES SHADE FARM PROVIDES
   c. JUST MODERN OPINIONS STAY CLEAR NOT WILD
   d. THESE ESCAPE CLASSES INSTEAD SAVE TREES TILL

FORM E (Cont.)

10. a. COUNTRY LED WAR OF MUSIC DANCED ALL
    b. WARM DAYS MOVE WHILE FAVORS DON'T LET
    c. FELL EIGHT YARDS SHOULD BURN SOMETHING SMOKE
    d. EGGS GROWING CLOSE PRETTY CLEAN SNOW LIES

11. a. COMPLETE HIS MOVEMENT ARRIVES NEAR SCHOOL ON
    b. SMALL TRIPS WON'T BUY BROKEN LIGHT NEXT
    c. LIE AMONG THOSE WILD COUNTRY GARDEN BURNED
    d. SHOPE BEST DURING PARTIES THEIR YEAR NEARLY

12. a. LAY SUCH FEAR PAID A HEAVY PURPOSE
    b. NOT TOWARD WINDOWS NEAR CHAIRS THUS ARE
    c. PLEASURE SIMPLE FRIEND GOT WHAT ALL NINE
    d. TAKE ANYTHING ABOVE CLOUDS SEEM BRIGHT WHILE

13. a. SINCE GUARD SOLDIERS OF CONTROL KEEP BEAUTY
    b. EARTH ON SO HEAT ALLOWS FAMOUS HAT
    c. CHILDREN TOO SPOKE LAST BECAUSE SEVEN MILES
    d. UNDER NONE BURNED FINE NEARLY SINCE COLD

14. a. FEW YARDS TILL HEALTH STORES WARM PRESSES
    b. TO OBJECT WHILE SHE COULD CLEAR ENOUGH
    c. PEACE SEEMS KNOWN SPIRITS MET LITTLE SINGING
    d. GOVERNMENT POSTS YOUR PAIR TOOK WALKS FOR

15. a. HANG HEAVY BUT WHY UNTIL AN ARMY
    b. SCENE TODAY GROWS LONG QUITE TRUE WITHIN
    c. AND WAIT THREE COMMANDS MUST MEET CLOSE
    d. THOUGH WORTH DOLLARS IF SUCCESS MUST WAIT

16. a. CEASE CHANGE WEAR DRESSES WHILE LISTENING MADE
    b. FOR WHOM MOST SPARE MILLIONS SAFELY WATCH
    c. HEAVY LADIES THINK PRACTICE KEPT WHO DEALS
    d. WERE PLEASANT WHILE WARM DAYS ACCOUNT FOR

17. a. LAST IN BODY MOVEMENT THE SWEET MONEY
    b. FELL WHILE COLD SOFT BEINGS BUY THOUSANDS
    c. DURING SERVICE FEELS WRONG TILL IT PRESSED
    d. SHORT HUMAN HAIR FLIES GOING TILL THAN

18. a. ALTHOUGH DEEP RED COALS JUST NEEDS LONG
    b. COOKS HEAT ALMOST TWO WORDS PREPARED BEFORE
    c. EGGS SEVEN DRY CARS GATHERED SUCH FLOWERS
    d. SHIPS UNDER TALL METHODS REACH ABOVE REAL

19. a. HURTS BEYOND LONG REACH IS EASY TILL
    b. JUST GLAD DIFFERENT VALUES TEACH MINDS QUITE
    c. AMOUNT ACROSS THE BACK STORE ICE IN
    d. ALTHOUGH GROUPS TALK LATE YET MOST MAKE

FORM E (Cont.)

20. a. MORE HILLS LAY VILLAGES MILES WON'T PART
    b. ICE FINALLY STOPPED EIGHT STATES VALUE OF
    c. DOLLARS WARY HAND FREE HOLD YOUR PRETTY
    d. HOUSE EAST LAND YOURSELF DOWN WITH THOSE

21. a. MORE CLOTHES HAD NEVER CHANCED MEMBERS THAT
    b. BEDS CAN'T KNOW MUSIC AS POST CHIEF
    c. SAFE IF BETWEEN EARTH ITS WILD HOW
    d. GAMES THAT BEGIN PAST YOUR FILLAGE FOLLOWS

22. a. ALREADY TOOK COMMON WANTS OLD TRUTH KEPT
    b. SUMMER SHOULD DANCE SOON AMONG BOOKS BURN
    c. FOODS BUILD STRAIGHT TODAY SHOT SIX TREES
    d. PEACE AROUND EARTH WON'T CARE PAST DANCING

23. a. UNDER ICE FOR FISH ESCAPE BEYOND WAR
    b. VALLEY OFTEN GREW WISE LAST HOUR WENT
    c. IF BROKEN MEN ADD WATER EVEN TO
    d. BEHIND BUT JOY OF PUBLIC LAND SOMETIMES

24. a. DARES NOT SERVE COMPLETE AMOUNTS FEEL CROSSES
    b. SHOULD SIT UNDER WATER WORLD LEADS AGAINST
    c. MILES WHILE QUICKLY SING OUTSIDE IN HONOR
    d. STILL PLEASED SINCE COMING OUTSIDE STORES BUILD

25. a. GUARDS SPRINGING WHILE HANGING WHERE WEIGHT TIES
    b. EXPLAINS SOMETHING WE WATCH OIL PROBLEMS FELL
    c. DAY SAVE DOGS IN BROWN ONLY ACCORDING
    d. SAVE SOULS NEARLY LOST BESIDE FUTURE FAIR

SSI LIST - FORM F

1. a. MUST ACT BUSY TOMORROW AND STOP FOR
   b. WEST TILL LIFTING CLUBS KILLED BIRDS BEHIND
   c. DIRECT MARKET OF VALUE CAME FIVE WAVES
   d. FELL EIGHT YARDS SHOULD BURN WOMETHING SMOKE

2. a. FOR WHOM MOST SPARE MILLIONS SAFELY WATCH
   b. VALLEY OFTEN GREW WISE LAST HOUR WENT
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   b. FEW YARDS TILL HEALTH STORES WARM PRESSES
   c. WENT STRANGE QUICKLY MADE SEVEN TRAINS WON'T
   d. SHORT HUMAN HAIR FLIES GOING TILL THAN

4. a. NORTH BELOW THOSE TREES SHADE FARM PROVIDES
   b. LAST IN BODY MOVEMENT THE SWEET MONEY
   c. PEACE SEEMS KNOWN SPIRITS MET LITTLE SINGING
   d. ACROSS WHILE COMING FOR NONE WATCH FULL

5. a. OVER BUILDINGS WALK HARD LIKE WOOD ON
   b. FELL WHILE COLD SOFT BEINGS BUY THOUSANDS
   c. GROUPS BE COMMON WHILE UNDER STREAMS BUILDING
   d. ALREADY TOOK COMMON WANTS OLD TRUTH KEPT

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   c. CANNOT FIT SHOES FAST RATHER LOSE AFTER
   d. JUST GLAD DIFFERENT VALUES TEACH MINDS QUITE

8. a. UNDER NONE BURNED FINE NEARLY SINCE COLD
   b. DARES NOT SERVE COMPLETE AMOUNTS FEEL CROSSES
   c. SMALL TRIPS WON'T BUY BROKEN LIGHT NEXT
   d. WHILE UNDER NINE BIG MEETINGS BELONG KNOWN

9. a. DON'T WRITE LIKE STONE WILL GIVE PLEASURE
   b. LIKE CERTAIN ROOMS EXPRESS HER VOICE OUGHT
   c. BEDS CAN'T KNOW MUSIC AS POST CHIEF
   d. CROWDS WHEN NONE TURNS SUCH HAPPY COMPANY

FORM F (Cont.)

10. a. NEWS PLEASED EIGHT GIRLS UNDER BOXES PREPARE
    b. CLEAN THROUGH PAPER WHICH PROMISES ME GREAT
    c. TO OBJECT WHILE SHE COULD CLEAR ENOUGH
    d. PEACE AROUND EARTH WON'T CARE PAST DANCING

11. a. NEWS PLEASED EIGHT GIRLS UNDER BOXES PREPARE
    b. STILL PLEASED SINCE COMING OUTSIDE STORES BUILD
    c. MILES WHILE QUICKLY SING OUTSIDE IN HONOR
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    d. CENTS SOMETIMES KEEP BETWEEN WIDE ENOUGH SHOES

15. a. HEAVY LADIES THINK PRACTICE KEPT WHO DEALS
    b. IF BROKEN MEN ADD WATER EVEN TO
    c. SAFE IF BETWEEN EARTH ITS WILD HOW
    d. NOT TOWARD WINDOWS NEAR CHAIRS THUS ARE

16. a. NORTH PAST A BANK REMAINS ABLE TO
    b. HOUSE EAST LAND YOURSELF DOWN WITH THOSE
    c. SCENE TODAY GROWS LONG QUITE TRUE WITHIN
    d. SHOULD SIT UNDER WATER WORLD LEADS AGAINST

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    b. WAIT EASY UNTIL TAKEN MORE SCHOOLS OUGHT
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    b. EGGS SEVEN DRY CARS GATHERED SUCH FLOWERS
    c. GOVERNMENT POSTS YOUR PAIR TOOK WALKS FOR
    d. TAKE ANYTHING ABOVE CLOUDS SEEM BRIGHT WHILE

19. a. AND WAIT THREE COMMANDS MUST MEET CLOSE
    b. ICE FINALLY STOPPED EIGHT STATES VALUE OF
    c. MORE CLOTHES HAD NEVER CHANCED MEMBERS THAT
    d. SAVE SOULS NEARLY LOST BESIDE FUTURE PAIR

FORM F (Cont.)

20. a. IS CUT LAST WEEK SOON GAVE PRACTICE
    b. CHILDREN TOO SPOKE LAST BECAUSE SEVEN MILES
    c. THOUGH WORTH DOLLARS IF SUCCESS MUST WAIT
    d. CEASE CHANGE WEAR DRESSES WHILE LISTENING MADE

21. a. DURING SERVICE FEELS WRONG TILL IT PRESSED
    b. SEEM YOUNG HOWEVER SEND STRAIGHT AWAY FROM
    c. TAKE OUT WHOLE NUMBERS ALWAYS WENT AWAY
    d. CLEAR FROM CLOUDS ABOVE EARTH OPENS WIDE

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    b. COOKS HEAT ALMOST TWO WORDS PREPARED BEFORE
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    c. FOR WHOM MOST SPARE MILLIONS SAFELY WATCH
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SSI LIST - FORM G

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   c. DURING SERVICE FEELS WRONG TILL IT PRESSED
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SSI FORM G (Cont.)

10. a. HURTS BEYOND LONG REACH IS EASY TILL
    b. TASTES GREAT DURING DEATH RATHER BREAK WATER
    c. COMPLETE HIS MOVEMENT ARRIVES NEAR SCHOOL ON
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    b. STILL PLEASED SINCE COMING OUTSIDE STORES BUILD
    c. ALTHOUGH WOOD ACTS GAIN ALL VIEWING FUTURE
    d. DOLLARS WARY HAND FREE HOLD YOUR PRETTY

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    b. PEACE AROUND EARTH WON'T CARE PAST DANCING
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18. a. COOKS HEAT ALMOST TWO WORDS PREPARED BEFORE
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    c. NEWS PLEASED EIGHT GIRLS UNDER BOXES PREPARE
    d. TAKE OUT WHOLE NUMBERS ALWAYS WENT AWAY

SSI FORM G (Cont.)

20. a. NOT TOWARD WINDOWS NEAR CHAIRS THUS ARE
    b. PLEASURE SIMPLE FRIEND GOT WHAT ALL NINE
    c. EXPLAINS SOMETHING WE WATCH OIL PROBLEMS FELL
    d. SHOULD SIT UNDER WATER WORLD LEADS AGAINST

21. a. FELL EIGHT YARDS SHOULD BURN SOMETHING SMOKE
    b. VALLEY OFTEN GREW WISE LAST HOUR WENT
    c. WEST TILL LIFTING CLUBS KILLED BIRDS BEHIND
    d. SINGLE FINE SEEMS WITH WEIGHT HANGING LOTS

22. a. CROWDS WHEN NONE TURNS SUCH HAPPY COMPANY
    b. FEW YARDS TILL HEALTH STORES WARM PRESSES
    c. MORE CLOTHES HAD NEVER CHANCED MEMBERS THAT
    d. ALTHOUGH DEEP RED COALS JUST NEEDS LONG

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    b. ALTHOUGH GROUPS TALK LATE YET MOST MAKE
    c. PEACE SEEMS KNOWN SPIRITS MET LITTLE SINGING
    d. SHOP BEST DURING PARTIES THEIR YEAR NEARLY

APPENDIX C

APPENDIX C. INFORMED CONSENT RELEASE FORM

1. I, _____, freely and voluntarily consent to serve as a subject in a scientific study of speech perception conducted by Dr. Michael R. Chial, Mr. Michael Stewart, and other student assistants.

2. I understand that the purpose of the study is to determine the reliability and validity of a particular method of measurement of speech perception which may be of future clinical usefulness.

3. I understand that I will not be exposed to any experimental conditions which constitute a threat to my hearing, nor to my physical or psychological well-being.

4. I understand that data gathered from me for this experiment are confidential, that no information uniquely identified with me will be made available to other persons or agencies, and that any publication of the results of this study will maintain anonymity.

5. I engage in this study freely, without payment to me or from me, and without implication of personal benefit. I understand that I may cease participation in the study at any time.

6. I have had the opportunity to ask questions about the nature and purpose of the study, and I have been provided with a copy of this written informed consent form. I understand that upon completion of the study, and at my request, I can obtain additional explanation about the study.

Date: _____ Signed: _____

APPENDIX D

APPENDIX D. STANDARDIZED SSI TEST INSTRUCTIONS

During the following listening task you will be asked to identify different sentences. The sentences have no meaning. First, you will hear the speaker reading five sentences in quiet. Next you will hear two sets of nine sentences each presented with some type of competing message. The signal light will come on each time a sentence is read. Your task is to listen for and circle the correct sentence for each of the 23 four-alternative items on the answer sheet in front of you marked SSI training material.

During the next part of this session, you will hear the speaker reading ten different 25-item lists of sentences. Each list will be presented with a competing message. The loudness of the competing message will vary from list to list. Each time a sentence is read, the signal light will go on. This is to let you know a sentence is being presented. Some of the sentences will be very difficult to hear, so you will have to watch for the signal and listen carefully. Continue to identify each sentence by circling either A, B, C, or D for each of the 25 items on all ten lists. Each sentence list is on the clipboard in front of you in the proper order. There is a different response sheet for each sentence list. You will be given a break after the first five lists have been completed.

APPENDIX E

APPENDIX E. SSI PRACTICE TEST

1. a. CRY DURING LABOR USUALLY PLEASES WISE MEN
   b. SEE MY YOUNG HOWEVER SEND STRAIGHT AWAY FROM
   c. FELLOW OFFICERS USUALLY REACH OCEANS WITH REASON
   d. IF ALLOWED MEASURE HOWEVER KEPT FEELING THERE

2. a. SHOULD SIT UNDER WATER WORLD LEADS AGAINST
   b. UNDER COOL MOUNTAINS JUST TURN FORTH DEMANDING
   c. YOU SAID COMPLETE GOING ACCORDING TO YOU
   d. NEED THAT CAR EASILY HAD AFFAIRS BEHIND

3. a. UNDERSTANDING WHICH GIRL ACCEPTS ENEMIES BETWEEN IT
   b. BE EASY ON BOARD VARIOUS BIG OFFICERS
   c. PEACE SEEMS KNOWN SPIRITS MET LITTLE SINGING
   d. OBJECTS SHOULD HAND BEHIND BAGS ARE

4. a. FOR THIRTY SOLDIERS NOTED MEETING THIS FARMER
   b. INSTEAD PROVE BATTLE RESULTS SETTLED INCLUDE TWO
   c. OUTSIDE ALTHOUGH BACK MARKETS GROW HOT OFTEN
   d. SHORT HUMAN HAIR FLIES GOING TELL THAN

5. a. PEACE BUT PERHAPS VALUES DEMAND PLEASURE SUDDENLY
   b. FOR MOVEMENT TEARS AS INSTEAD BREAK QUICKLY
   c. UNDER ICE FOR FISH ESCAPE BEYOND WAR
   d. TO ENJOY MATERIAL ISSUES ARE GETTING TOGETHER

6. a. SEEM YOUNG HOWEVER SEND STRAIGHT AWAY FROM
   b. IDEAS USUALLY KEEP NEW ACTS HAPPEN FIRST
   c. YOUR FAMOUS WOMEN INCLUDED CHILDREN SOMETIMES MARCH
   d. KEEP VARIOUS WISHES GET CONSIDERED MORE OFTEN

7. a. HALF DAYS VISIT BEHIND GLASS PIECES TAKEN
   b. PAST OBJECTS CAME NEARLY CLEAN ABOUT MONEY
   c. SUMMER SHOULD DANCE SOON AMONG BOOKS BURN
   d. INDEED AND COMPLETE COLORS SUDDENLY BECAME FAMOUS

8. a. MUST HURRY SUMMER ALONG THE CITY KNOWN
   b. SITS VERY STILL WHILE I ACCEPTED HEAVEN
   c. HAPPY VOICES CERTAINLY TOLD TEN HATS CAN'T
   d. SHOP BEST DURING PARTIES THEIR YEAR NEARLY

9. a. SAID QUICKLY DURING A FIGHT USUALLY PASS
   b. SAVES DOLLARS PAST MAN WOULD KNOW SIMPLE
   c. DUE TO THOSE THAT SAW A YOUNG
   d. BROTHER PAID BRIGHT MUSIC DOUBLED IN SCHOOL

SSI TRAINING MATERIAL (Cont.)

10. a. DIRECTS MARKET OF VALUE CAME FIVE WAVES
    b. EITHER DIRECTION SUDDENLY GOT COOL FRUIT CANNOT
    c. THAN SAIL QUICKLY INTO FOREIGN THINGS
    d. ADVANCED CONTROL PAIN LIKE SHE SAVES SALT

11. a. JUST THREE MEMBERS APPEAR PRETTY FLOWER
    b. EXPLAINS SOMETHING WE WATCH OIL PROBLEMS FELL
    c. CANNOT THINK SINCE SHE HAD SEVEN EASY
    d. FIRST CAME PAIN ACROSS SINCE COLLEGE LEFT

12. a. GOOD SOFT EGGS PROBABLY TOOK VALUES CLEAR
    b. FIGHT ACCORDING TO HIM NEARLY NONE CERTAIN
    c. ALTHOUGH DEEP RED COALS JUST NEEDS LONG
    d. QUICKLY KEPT LARGE TREES DEMAND MODERN MATERIAL

13. a. CLOTHES TWELVE SHIPS PROVIDE VARIOUS CONDITIONS UNDER
    b. KEPT FITTING BEAUTIFUL HATS CAN'T HAND DRESSES
    c. FELL EIGHT YEARS SHOULD BURN SOMETHING SMOKE
    d. FURTHER MY COMPANY WANTS MILK SUPPLY MUST

14. a. CAR ADVANCES FINALLY WOULD UNDERSTAND WELL WHAT
    b. BREAK PROMISES ON EVEN YOUR OWN HOME WON'T
    c. TODAY THOUGH ICE CAUSES BEAUTIFUL MOUNTAINS FELL
    d. LIKE CERTAIN ROOMS EXPRESS HER VOICE OUGHT

15. a. GUARDS SPRINGING WHILE HANGING WHERE WEIGHT TIES
    b. HAS MONEY GIVEN ALTHOUGH OUR EFFORT SETTLED
    c. AMONG WONDERFUL WOMEN KEEP VERY CLOSE UNTIL
    d. OUGHT WONDER UNTIL SUCCESSES INCHES ALONG GREEN

16. a. ALTHOUGH GROUPS TALK LATE YET MOST MAKE
    b. LOW EVERY BABY GROWS QUICKLY NOTICE ISSUE
    c. VISITED OUTSIDE PLACES SERVE DARK WATER MOVED
    d. CONTAINS NATURAL LIGHT ENTERS ESPECIALLY WHEN CLOUDS

17. a. VERY SHORT SISTERS ALWAYS AGREE ALTHOUGH NO
    b. WATER FISH UNTIL NEXT SET IS LIKE
    c. COLOR CERTAINLY DID HAVE FAMILY TALKS KEPT
    d. MOVING ACROSS MOUNTAINS SEVERAL SOLDIERS RETURNING

18. a. KEPT MOST CASES HAND NORTH UNTIL EXPERIENCE
    b. FINALLY ARRIVED TODAY PROBABLY WAS SHORT MANNERED
    c. BECAME WARM TODAY OR NINE LIVES SHALL
    d. DOLLARS WARY HAND FREE HOLD YOUR PRETTY

SSI TRAINING MATERIAL (Cont.)

19. a. LOVE ACCEPTS ANYTHING DEAD OR TALK ABOUT
    b. HIM ORDER THAT BELONG NEARLY LIVES BY
    c. HANG HEAVY BUT WHY UNTIL AN ARMY
    d. ABOUT BEAUTY DECIDE TO KISS YOUR AFTERNOON

20. a. SAFE MEETING CHILDREN NEARLY WON'T WHILE
    b. STATIONS PAGE MEMBERS UPON EXPERIENCE MADE
    c. PEACE AROUND EARTH WON'T CARE PAST DANCING
    d. MORE PLEASURE ESPECIALLY SENDS MEN FORTH NEAR

21. a. THEM ENJOYED DARK SHIPS SHOULD GO FORTH
    b. MASTER AGREE WITH YOURSELF ACT CERTAIN EXPERIENCE
    c. GATE QUICKLY KEPT INSTEAD TWO SHIPS MET
    d. SEASON PASS COULD ACCEPT ACTIONS EXCEPT SOMETIMES

22. a. FINALLY ARRIVED TODAY PROBABLY WAS SHORT MANNERED
    b. LAST IN BODY MOVEMENT THE SWEET MONEY
    c. IS SUCH FEAR PAID A HEAVY PURPOSE
    d. CANNOT FIT SHOES FAST RATHER LOSE AFTER

23. a. CLEAN THROUGH PAPER WHICH PROMISES ME THINGS
    b. WEST TILL LIFTING CLUBS KILLED BIRDS BEHIND
    c. EARTH ON SO HEAT ALLOWS FAMOUS HAT
    d. MONEY WENT STRAIGHT HOURS WERE MOVING ALONE

APPENDIX F

APPENDIX F. DETERMINATION OF MCRs

INTRODUCTION

A pilot study was necessary to determine four MCR values which would allow construction of the linear portion of the SSI psychometric functions for all competing message conditions. It was expected the various competing messages used in this study would exhibit differential masking ability dependent upon their respective temporal, spectral and semantic content characteristics and thus require different MCR values to construct psychometric functions. It became evident after exposing listeners to the various competing messages that a difference in masking ability did exist among competing messages. It appears that the stimuli can be separated into three main classifications based on type and degree of masking ability.

The masking ability of the first type is dominated by a semantic content factor which apparently increases masking efficiency secondary to a perceptual masking phenomenon. The MT 8 and MT 8 + 1 stimuli are included in this classification. It is interesting to note that although perceptual gaps exist in the MT 8 + 1 stimuli, due to the 10 dB difference between a temporally continuous background and a temporally discontinuous foreground, masking ability seems to be equivalent to the MT 8 competing message. This may be due to the complexity of perceptual events that take place within that signal (i.e., speech in foreground and background) and because the same speaker appears in the background, foreground, and target sentence.

The masking ability of the second type of competing stimulus (DEN MT 8) is dominated by the physical spectrum. Here the primary stimuli are masked by a continuous noise that has spectral characteristics similar to real speech. Although the spectrum of the DEN MT stimulus is identical to that of the MT 8 stimulus, it is void of semantic content and thus lacks the perceptual masking component. The masking efficiency of this type of stimulus appears to be less efficient than the first type but more efficient than the third type.

The third type of stimulus consists of DEN MT + 1, MT 8 + DEN 1 and DEN MT + DEN 1. The relatively poor masking ability of this type of stimulus is probably related to the temporal discontinuity (perceptual gaps) inherent in the masking spectrum. The listener is able to hear words or phonemes during the off-time of the foreground signal even at relatively negative MCR values. During the foreground off-time the MCR improves 10 dB. Although these 10 dB acoustic "windows" are not as large as those that exist in a temporally discontinuous foreground-only stimulus (i.e., single talker), their existence and random occurrence probably serve to decrease masking efficiency and increases variability in subject performance.

The purpose of this pilot study was to determine MCR values which are appropriate for construction of the linear portion of the SSI psychometric function for each type of stimulus.

SUBJECTS

Five normal-hearing adult subjects were selected according to availability and previously described criteria. All five subjects

served in determining MCR values for the MT 8 stimulus and three subjects were used to determine MCR values for the remaining stimuli.

APPARATUS

The instrumentation employed was that which will be used in the main experiment (see Figure 1).

PROCEDURE

The subjects were screened, read standardized instructions, and seated in an audiometric test booth (IAC Model 1200 A). Each subject participated in a practice session consisting of one list of 21 items presented under an earphone to the test ear at 40 dB SL. The first three items were presented in quiet to familiarize the subject with the four-alternative forced-choice paradigm. The next 18 items were presented with the ipsilateral MT 8 competing message adjusted to provide an MCR of -2 dB.

Following the practice session, each subject received one 25-item SSI test paired ipsilaterally with the MT 8 competing message at each of six MCRs ranging in two dB steps from -16 to -4 dB. The subjects task for each test was to choose the correct sentence from the four-alternative choices for each item.

Following completion of this portion of the pilot study, three subjects were used to define appropriate experimental MCR values for the remaining stimuli. The procedure used for this part of the pilot study was similar to that used in the first part. However, the range of MCR values were necessarily different depending upon the competing message stimulus and the step size was increased from 2 dB to 4 dB to quickly bracket the 20-100% performance range.

DATA ANALYSIS AND DISCUSSION

Mean percent-correct and standard deviation values for the MT 8 competing message stimulus were computed for each of the six MCR values and a resulting psychometric function was plotted (see Table F-1 and Figure F-1). Mean percent-correct and standard deviation values for the remaining competing message stimuli at their respective MCR values are also shown in Table F-1. Table F-2 reveals the slope, 50% masking efficiency value, intercept, and correlation (r) between performance score and MCR values for the MT 8 stimulus.

On the basis of these data, the MCR values listed in Table F-3 were used in the main experiment to construct psychometric functions for the various competing message stimuli. It was hopeful that use of the 2 dB step size between MCR values would produce more data points on the linear portion of the psychometric functions even for stimuli which may have relatively steep slopes. This would allow a more precisely defined psychometric function.

Table F-1. Means and standard deviations (% correct) of competing message stimuli scores at pilot MCR values.

COMPETING MESSAGE	MCR VALUES (dB)							
	-24	-20	-16	-14	-12	-10	-8	-4
MT 8 (N = 5)								
$\bar{x}$			17.3	32.8	48	56	68.8	100
S.D.			10	9.9	7.4	15.8	5.2	-0-
MT 8 + 1 (N = 3)								
$\bar{x}$			33.3		53.3		85	100
S.D.			11.5		16.1		8.3	-0-
DEN MT (N = 3)								
$\bar{x}$		22.6	52.3		64		97.3	-0-
S.D.		6.1	4.6		6.9		2.3	
MT 8 + DEN 1 (N = 3)								
$\bar{x}$		17	34.6		72		97.3	-0-
S.D.		8.3	2.3		6.9		4.6	-0-
DEN MT + 1 (N = 3)								
$\bar{x}$	28	60	68		100			
S.D.	5.6	5.6	6.9		-0-			
DEN MT + DEN 1 (N = 3)								
$\bar{x}$	26.6	69.3	81.3		100			
S.D.	2.3	9.2	12.2		-0-			

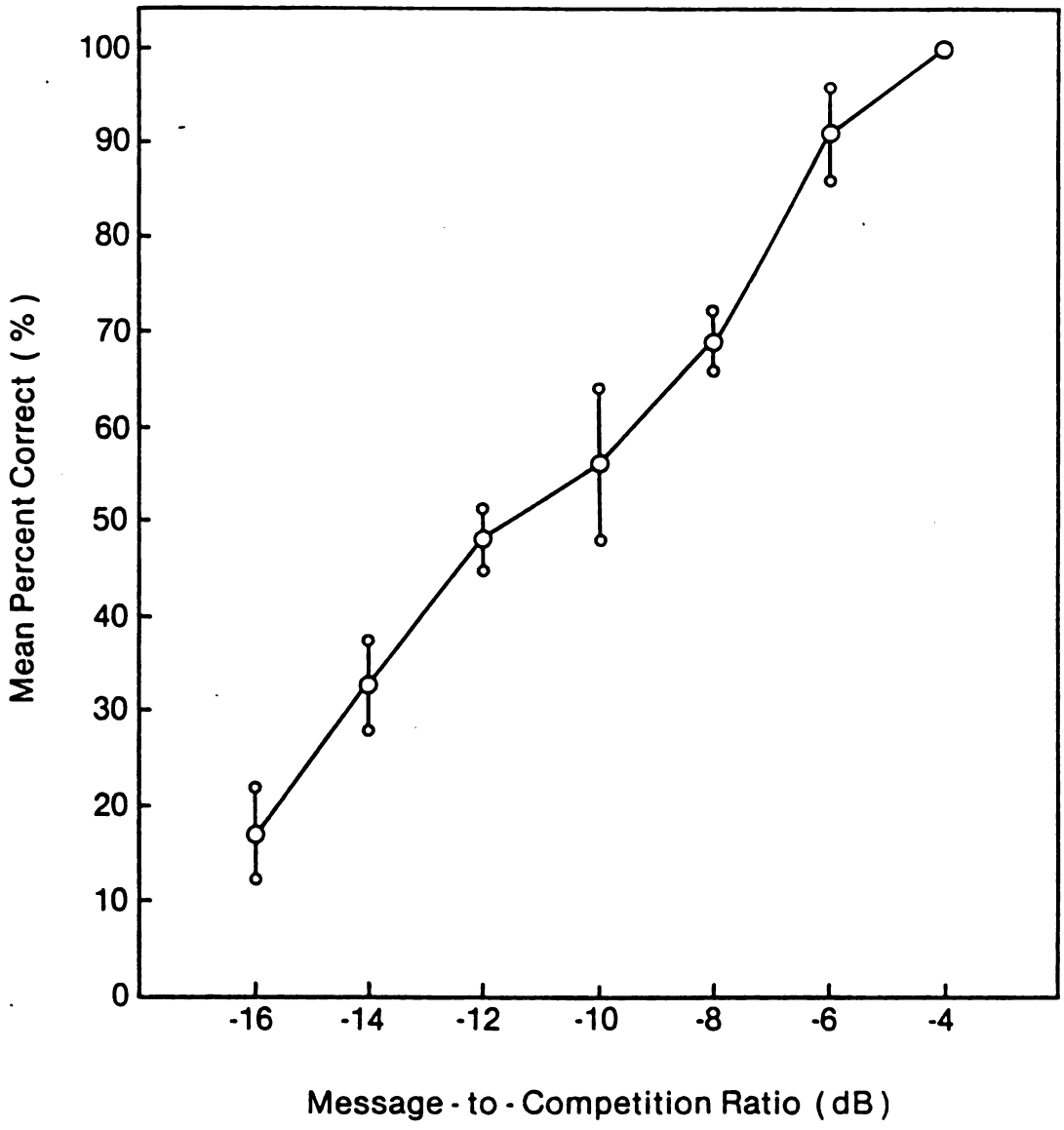

Figure F-1. Mean percent-correct scores for competing message MT 8 as a function of message-to-competition ratio. Each datum represents observations of 5 normal-hearing adult subjects tested monaurally. Vertical lines denote $\pm$ 1 standard deviation.

Table F-2. Psychometric function slope, 50% masking efficiency value, intercept, and correlation (r) for MT 8 competing message stimulus (N = 5).

	SLOPE	50% MASKING EFFICIENCY VALUE	INTERCEPT	r
$\bar{x}$	5.8%/dB	-11.36 dB	115.84%	94.2
S.D.	1.5	1.7	17.2	.043

Table F-3. Competing message MCR values chosen for experimental use.

COMPETING MESSAGE	EXPERIMENTAL MCR VALUE (dB)
MT 8	-14, -12, -10, -8
MT 8 + 1	-14, -12, -10, -8
DEN MT	-18, -16, -14, -12
DEN MT + DEN 1	-22, -20, -18, -16
DEN MT + 1	-22, -20, -18, -16
MT 8 + DEN 1	-20, -18, -16, -14

APPENDIX G

APPENDIX G. SSI TEST PROTOCOL

Project Name_____ Experimenter _____

Subject Identification:

Name _____ Number _____

Informed Consent Form Signed? Yes___ No ___

Audiologic Screening Results:

Criteria Met?
Right ear Yes___ No ___
Left ear Yes___ No ___

Experimental Session:

Date:_____ Start Time: _____ Finish Time: _____

Test Ear: _____ SRT: _____Primary HTL: _____

Instr. Given? _____ Cal.? _____ Prac. Done? _____

Presentation Order	List #	Competing Message	HTL	Score
_____	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _
_____	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _

Adaptive Procedure? Yes __ No __

_____	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _
_____	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _

Reliability Test-Retest			1st	2nd
_____	_ _ _ _	_ _ _ _	___ /	___
_____	_ _ _ _	_ _ _ _	___ /	___

Debriefing

Did you develop a listening strategy? Yes ___ No ___

How many? _____ Explain _____

_____

Did task become easier? Yes ___ No ___

Explain _____

_____

APPENDIX H

Appendix H. Percent-correct scores of the twelve normal-hearing subjects in each group as a function of competing message and message-to-competition ratio (AB).

GROUP I

SUBJECTS	MT 8 + DEN 1				DEN MT + 1			
	-14	-16	-18	-20	-16	-18	-20	-22
1	84	48	32	36	76	40	28	32
2	68	72	56	24	80	68	32	60
3	72	60	40	44	68	52	32	40
4	84	48	44	40	72	40	52	36
5	68	56	52	32	80	68	36	24
6	76	64	56	40	72	72	56	24
7	84	52	48	32	60	44	24	24
8	96	64	32	44	100	84	56	24
9	64	52	56	24	60	76	60	40
10	96	68	60	28	88	84	32	24
11	60	72	28	44	80	60	56	40
12	88	64	68	40	68	60	52	28
$\bar{X}$ % correct	78.3	60	47.6	35.6	75.3	62.3	43	33
S.D. (%)	12.1	8.6	12.5	7.5	11.4	15.7	13.3	10.8
Range (%)	36	24	40	20	40	44	32	36

Appendix H. (continued)

GROUP II

SUBJECTS	MT 8				DEN MT			
	- 8	-10	-12	-14	-12	-14	-16	-18
1	72	44	32	32	48	60	32	36
2	76	44	36	44	60	56	36	48
3	100	76	32	32	84	64	36	44
4	84	80	40	28	60	52	36	44
5	84	40	44	24	68	48	32	24
6	92	44	60	28	60	52	28	36
7	80	72	64	28	68	24	24	24
8	68	52	68	24	64	56	48	36
9	84	64	44	24	60	48	28	24
10	64	64	52	24	60	44	32	40
11	84	72	48	24	68	60	44	32
12	80	52	52	24	60	60	44	32
$\bar{X}$ % Correct	80.6	58.6	47.6	28	63.3	52	35	35
S.D. (%)	9.9	14.3	11.9	5.9	8.4	10.6	7.2	8.2
Range (%)	36	40	36	20	36	36	24	24

Appendix H. (continued)

GROUP III

SUBJECTS	MT 8 _ 1				DEN MT + DEN 1			
	- 8	-10	-12	-14	-16	-18	-20	-22
1	76	44	28	44	88	68	40	52
2	88	72	36	40	96	72	40	28
3	88	60	36	60	80	72	44	56
4*	76	52	44	32	84	76	48	52
5	76	56	60	36	72	64	60	40
6	84	80	60	36	68	72	60	40
7	88	76	60	24	88	68	48	40
8	72	60	48	28	88	64	60	40
9	68	56	32	24	64	68	32	24
10	92	80	48	28	100	60	52	32
11**	76	64	52	24	76	80	64	56
12	76	40	32	28	80	76	44	36
$\bar{X}$ % correct	80	61.6	44.6	33.6	82	70	49.3	41.3
S.D. (%)	7.6	13.2	11.7	10.5	10.8	5.7	9.9	10.6
Range (%)	24	40	32	36	36	16	32	32

*Scored 32% correct at -24 dB MCR for DEN MT + DEN 1

**Scored 40% correct at -24dB MCR for DEN MT + DEN 1

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